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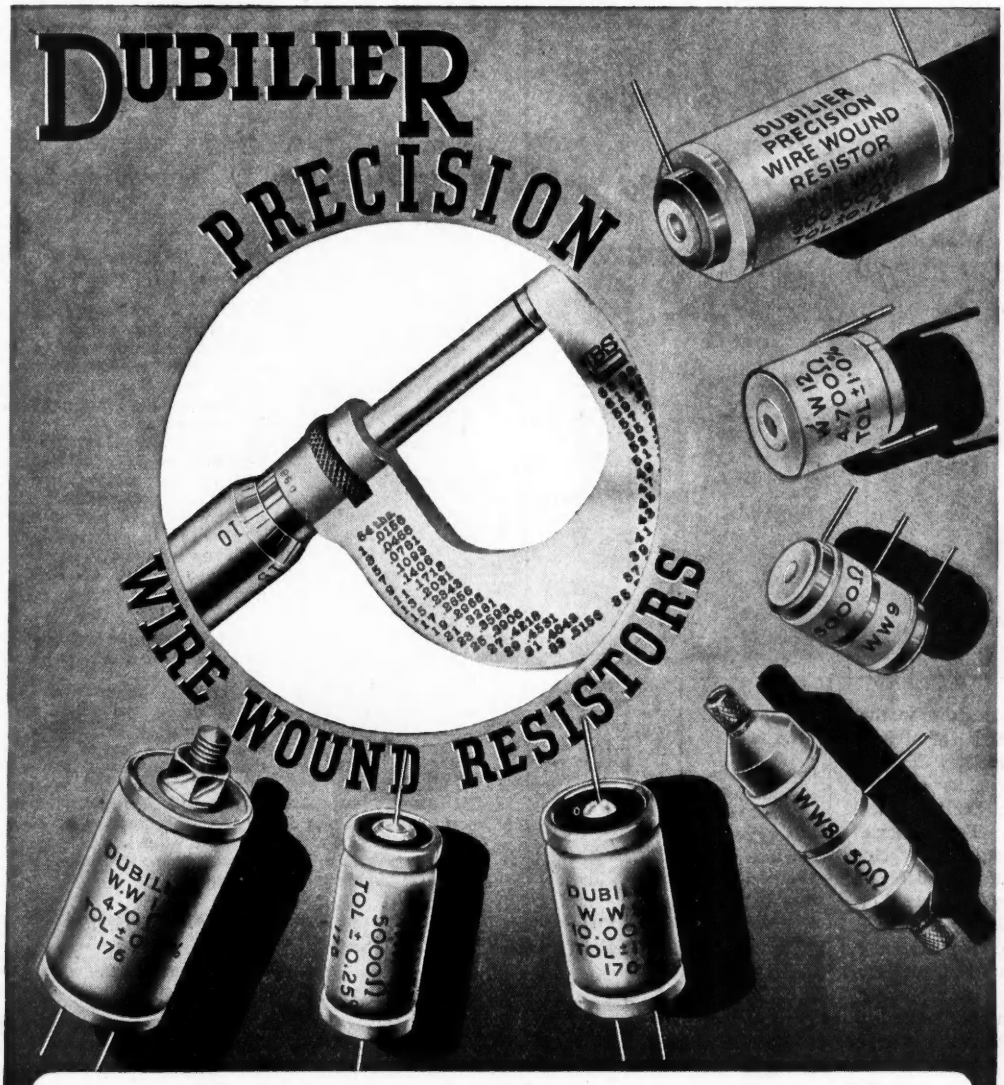

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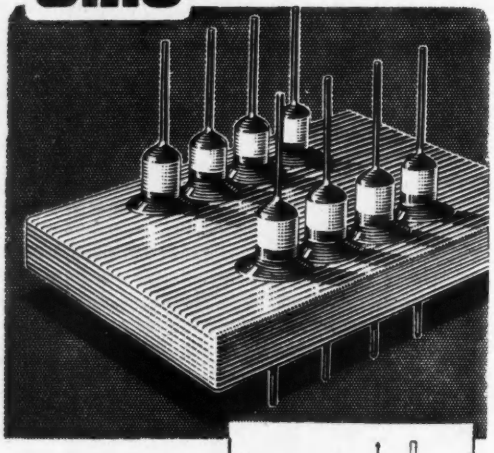

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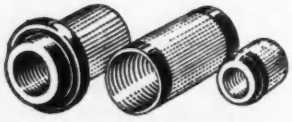

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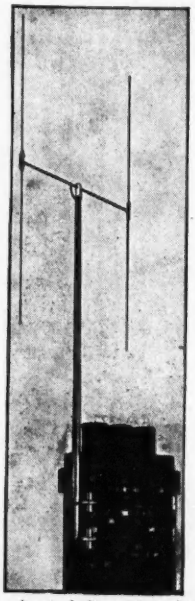

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Q. 21. *Is steel the best type of metal for manufacture of television aerials?*

A. 21. Not necessarily. Copper alloys are normally used for horizontal wire aerials, but in rod or tube form the cost of copper alloys would rise very considerably before it would be possible to reach the rigidity which is necessary to prevent mechanical distortion during assembly, erection, or under gale conditions (see Question 9 repeated below).
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Q. 9. *Why make television aerials of expensive rigid construction? Will a wire not do just as well?*

A. 9. A television aerial is really a tuned circuit which has been pulled out of compact shape. It therefore possesses a measure of selectivity. The reason for making the element of fairly large diameter is because it is known that this flattens the response and thus makes it more certain to produce high definition (sharp focus). This particularly applies now that the band width of the transmission has been increased, and if receiver designers take advantage of the higher quality of transmission, a deterioration of definition might be observed if the present rigid dipole element were replaced by, say, 7/22 copper wire.
to be continued . . .

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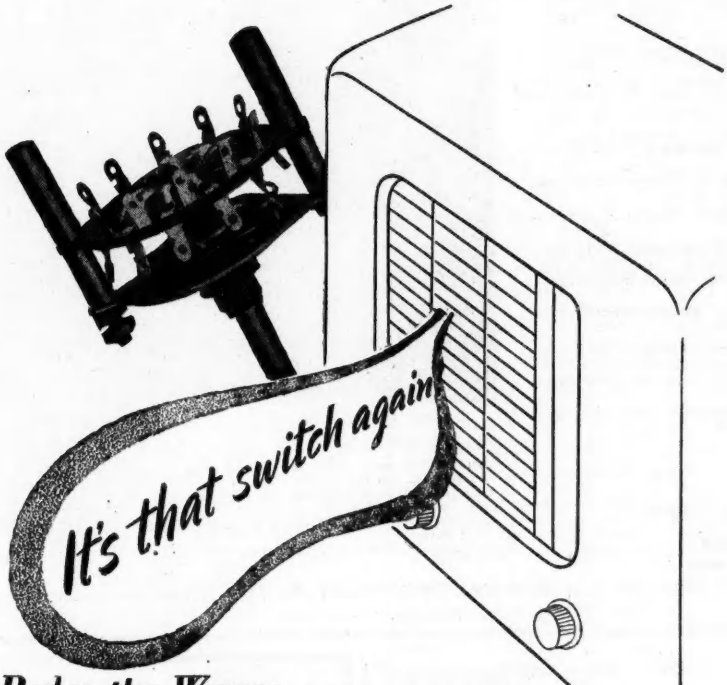

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Electronic Engineering

MARCH, 1947

Volume XIX. **No. 229.**

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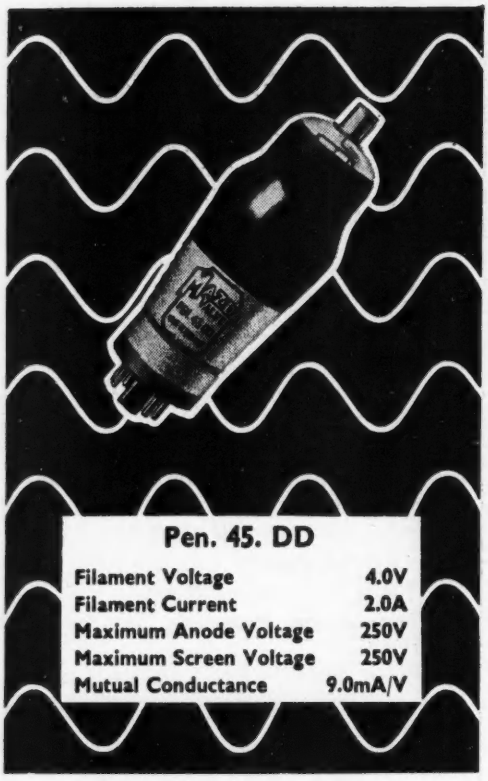

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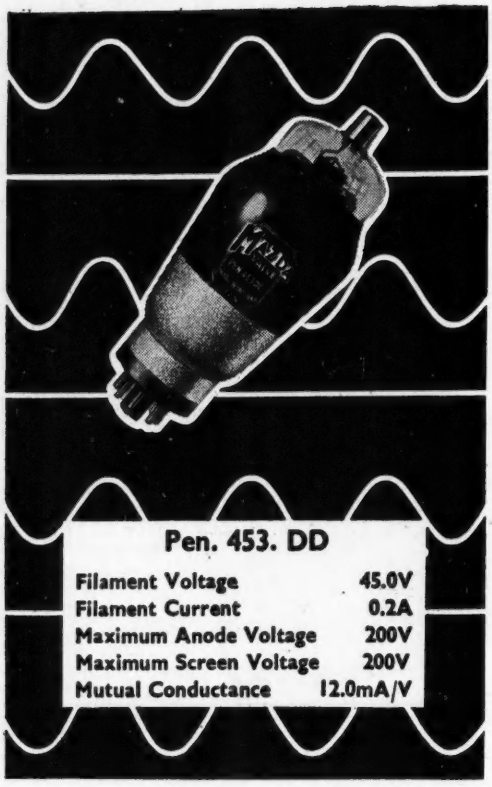

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K

IN his Editorial note in the February *Wireless Engineer*, Prof. G. W. O. Howe refers to an article in the Australian *Proc. I.R.E.* advocating a more rigid adherence to standard terms and symbols.

He has anticipated a note on similar lines which was overdue in this Journal. We couldn't agree more, but standardisation seems one of those things that is easy to recommend and less easy to carry out in practice. We should hate to undertake a wholesale alteration of authors' MS. to bring the symbols into line with agreed standards, especially as opinions are by no means unanimous on the present standards, in spite of B.S.I. publications.

Prof. Howe has quoted the original author, however, on several important points on which there can be no argument. The abbreviations for the multiples and sub-multiples of the units should be quite definite and allow of no variations. They cannot conflict with any personal ideas of what is right or convenient, and their misuse is only a bad habit which requires very little effort to break.

There are two outstanding examples of wrong abbreviations: mF. for microfarad and mc. for megacycle. As the article says: "No one would dream of using mV. for microvolt," and it is no more effort to write μ than m. The use of pF for μμF is also an advantage and saves a little time, although the Americans do not seem to have taken to it kindly. In fact, one dictionary of electronic terms refers to pF. as an obsolete term for micromicrofarads, still used in Britain.

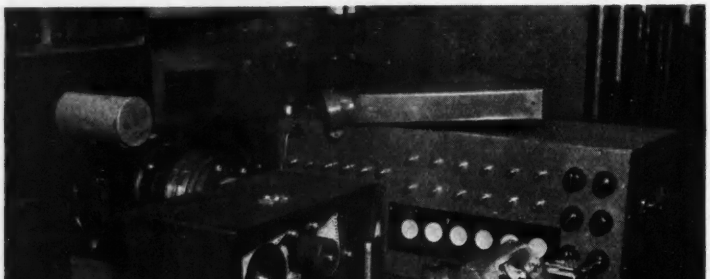
Then there is the vexed question of "k" for 1,000. The growing use of K in circuit diagrams to signify thousands of ohms is to be commended—it has no ambiguity, saves space, and is logical, especially if it is followed by the Ω sign.

But for some reason, when the sub-multiple symbols were standardised, k was adopted for 1,000 instead of K. Presumably this was by international arrangement, but the rule has nothing whatever to commend it. It is illogical and inconsistent with all the other standard sub-multiples and multiples which we are being encouraged to use. It is this sort of thing which provides an argument for those who wish to follow their own rules: "Why should we adopt standards which are inconsistent in themselves?"

This odd "k" is an eyesore in every electrical journal: kV., kVA, kW. Why not KV., KVAR, Kc/s., which look like real power engineering?

It may not be practicable to enforce observance of all the standards at the present, but we may attempt to remove one inconsistency and thus bring about an improvement. The proper use of K is a step forward to which there can be no objection, and from now on this journal will use K as a rightful abbreviation for Kilo.

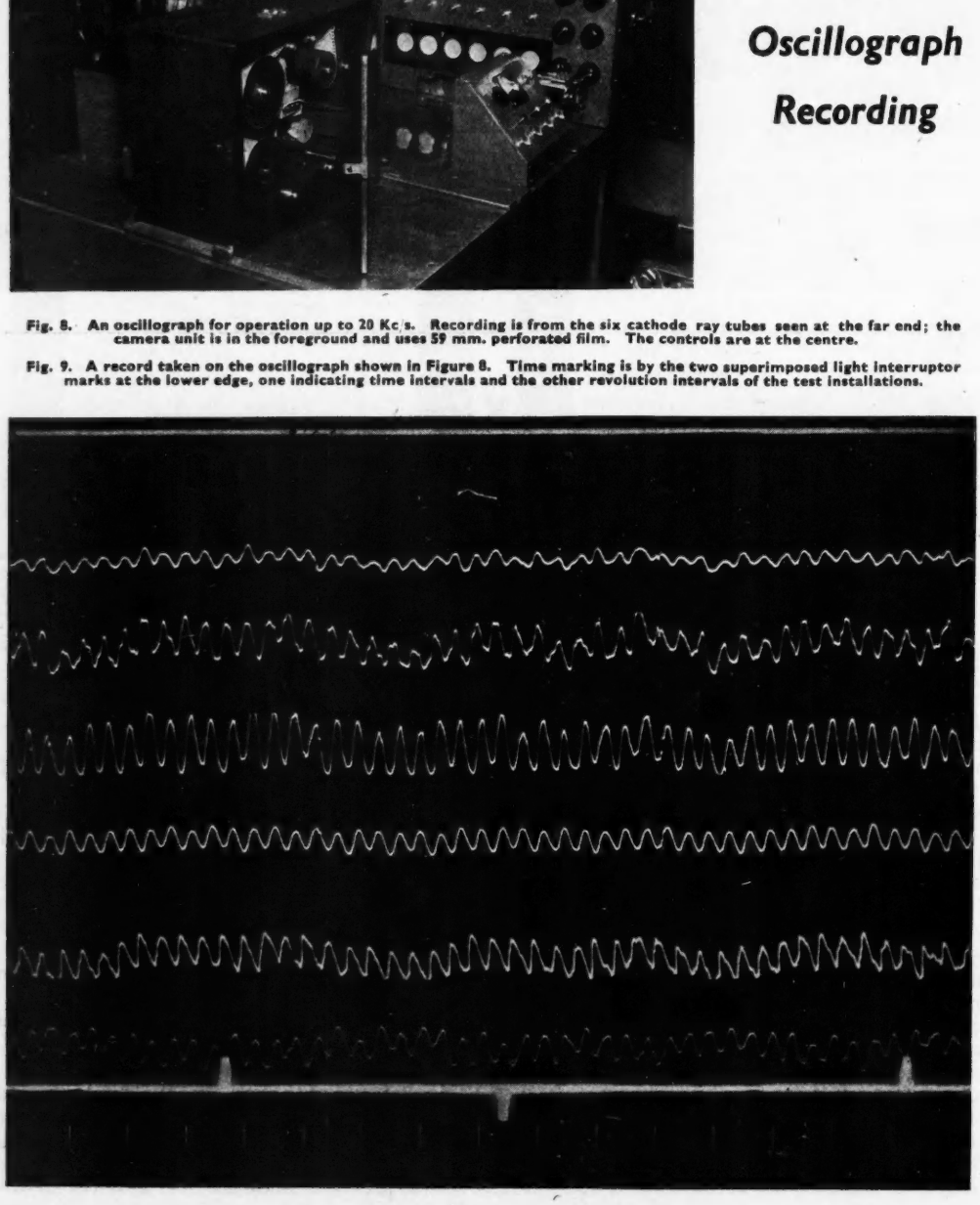
Having heard the first blast of the trumpet, perhaps our friends of the electrical press and the *Wireless Engineer* in particular, will support us in the campaign for consistent contractions!



High-Speed Multi-Oscillograph Recording

Fig. 8. An oscillograph for operation up to 20 Kc/s. Recording is from the six cathode ray tubes seen at the far end; the camera unit is in the foreground and uses 59 mm. perforated film. The controls are at the centre.

Fig. 9. A record taken on the oscillograph shown in Figure 8. Time marking is by the two superimposed light interruptor marks at the lower edge, one indicating time intervals and the other revolution intervals of the test installations.



A Modern Vibration Measurement Laboratory

Part I — A Study of the Conditions to be Satisfied in Vibration Measurement Work

By A. J. COGMAN*

IN recent years the investigation and solution of mechanical vibration problems have become of considerable importance. The demand for increased output of power plants, often in combination with the necessity for weight reduction, has resulted in the detailed study of vibration stresses as a standard feature of design work in many branches of engineering, particularly in connexion with metal-bladed aircraft propellers, reciprocating engines and of late with gas turbines.

In this work, measurements may be made of actual vibration deflections in space or, by using the comparatively modern technique associated with the electric strain gauge, measurements of the alternating stresses due to vibration in a structure. The latter method has greater advantages, since in nearly all cases the alternating stress is the quantity which must be known, and vibration deflection measurements only enable the stresses in a structure to be known after calculations involving the deflection measurements have been made.

The technique of measuring stresses directly has depended on the wire strain gauge. While this device is to be dealt with in greater details in a subsequent article, it is necessary at this stage to consider its main principles as this will facilitate an understanding of the requirements of apparatus for stress measurement.

The electric strain gauge makes use of the fact that a wire conductor exhibits a change of resistance proportional to the mechanical strain that takes place in it when it is extended or compressed above or below its normal length.

In the practical form, the wire strain gauge consists of a close zig-zag of wire embedded in a thin wafer of insulating material, usually impregnated paper of some kind (Fig. 1). The gauge is cemented firmly to the test surface, with the loops of the zig-zag in the axis along which it is desired to measure strains. The wire has end leads of stronger material spot welded on to its ends.

If the test surface undergoes strain, the wire grid will be extended or compressed according to the nature of the strain present, *i.e.*, whether it is tensible or compressive.

The resistance measured across the gauge ends will change in such a manner that

$$\frac{\text{Fractional change of resistance}}{\text{Fractional strain}} = \text{Constant}$$

The constant factor is known as the "strain sensitivity" of the gauge material, and is sensibly constant for wire samples taken from a given metal.

Since this constant may be determined experimentally for the wire used for manufacture of a batch of gauges, and the resistance change may be measured, the mechanical strain and hence the stress where the gauge is attached may be evaluated.

The main problem in vibration stress measurement is, therefore, the translation of resistance change into some form of oscillograph record, and of obtaining direct measurement of the resistance change when measurement of steady stresses is required. Several types of strain gauge are shown in Fig. 2.

Vibrographs employed for the measurement of vibratory deflections in a structure are nearly always of the electro-magnetic velocity type, in which the lines of force of a magnet are cut by the turns of a coil. Variations in design are numerous, and all types may be said to have disadvantages from the engineering viewpoint; their worst feature usually is their susceptibility to shock excitation at their fundamental natural frequency.

Frequency Ranges and an Outline of their Scope

There are in general, three frequency ranges into which apparatus can be grouped, *i.e.*:

Zero and low frequencies up to 2 c/s. (120 c/min.): mid frequency range, 2 c/s. to 1,500 c/s. (120-90,000 c/min.); high frequency range up to 20 kc/s. (1,200,000 c/min.).

The lowest range includes steady (or 'zero frequency") stresses which may be set up in a structure in combination with vibratory stresses; it is frequently necessary that such values of stress be known, consequently

* Late of Vibration Dept., de Havilland Propellors, Ltd.

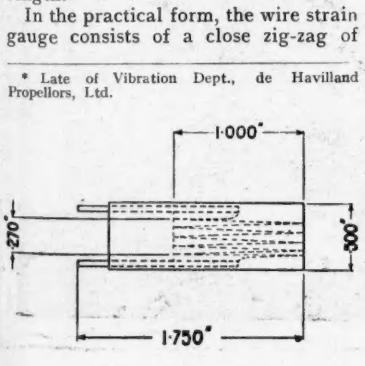


Fig. 1 (left) The basic constructional details of the wire strain gauge. The strain sensitive wire may be in the form of a flattened helix or a close zig-zag.

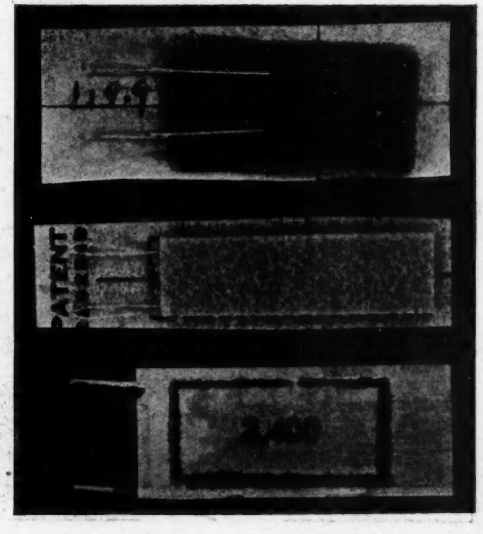


Fig. 2 (right) A group of typical strain gauges :–

(top) Baldwin Southwark 120 Ω type.

(centre) Baldwin Southwark 500 Ω type.

(below) de Havilland 2,400 Ω bakelite impregnated type.

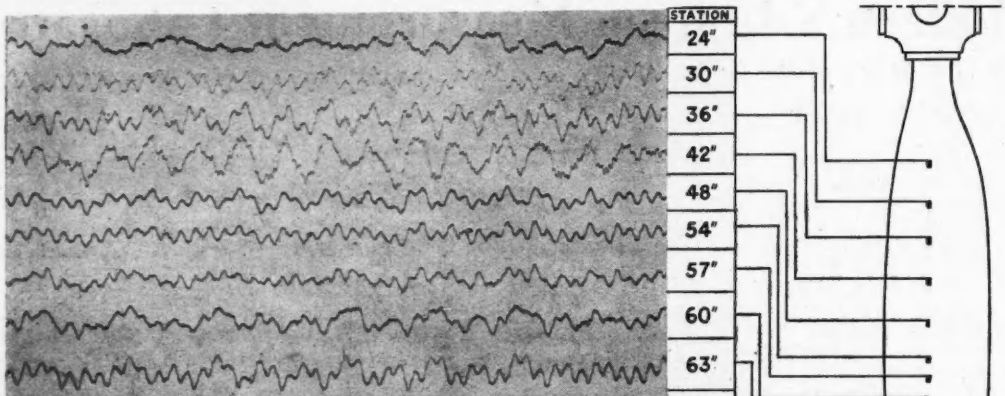
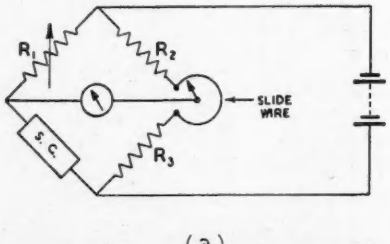


Fig. 3. Record taken on the apparatus shown in Fig. 4. showing the 12 stress records and the time marking traces.

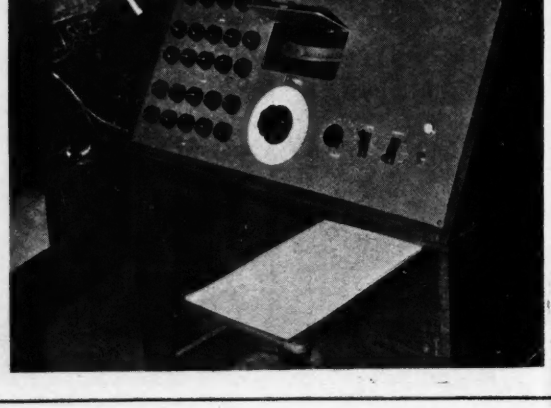
Fig. 4 (lower left). Partial view of the apparatus used to produce the record shown in Fig. 3. Four stress recorder amplifiers are installed in each of the racks shown, while the monitor tubes are visible in the mirrors at the top. The instrument panel at the top of the picture shows the operator the engine conditions at the time of recording.

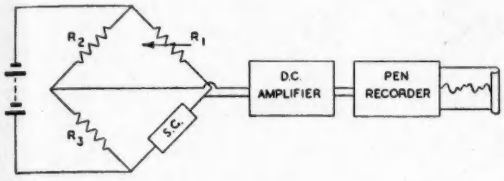
Fig. 5a. Simple manually operated bridge for steady stress measurement. R_1: Balancing resistor adjusted to give an initial zero reading, R_2 and R_3: Equal ratio arms. The slide wire has a scale calibrated in percentage change of resistance relative to R_2 and R_3: Changes in the strain gauge resistance may thus be measured.

Fig. 6. A strain gauge steady stress bridge operating on the principle of Fig. 5a but with provision for 10 strain gauges. A sensitive galvanometer is built in.



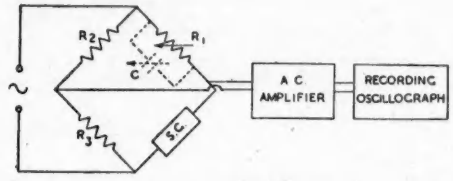
(a)





(b)

Fig. 5b. The bridge circuit of Fig. 5a with no calibrated variable element. Changes of potential are amplified by the D.C. amplifier and recorded by the pen and chart recorder.



(c)

Fig. 5c. Bridge fed with A.C. at suitable voltage, capacity balance being provided by C if necessary. The balance voltages are alternating and are registered by the A.C. amplifier and oscillograph.

apparatus has been developed to deal with this branch of stress measurement as well as true vibration measurement.

Slowly varying stresses may be due to periodic deformation of large structures having low frequencies, such as building frameworks or bridges, or the variation may be of the type experienced in airframe structures in flight, due to a change of flying conditions; these examples are quoted merely to outline the requirements which may have to be met in practice.

It is also of note that it is in this low frequency range that temperature compensation of strain gauges is necessary; the matter will be dealt with in some detail in a later article.

The second range quoted above, *i.e.*, 2-1,500 c/s. (120-90,000 c/min.) is the range which has probably, up to the present time, occupied the position of greatest importance in vibration measurement work. It is in this frequency range that vibrations excited by aircraft engines lie. Such vibrations were probably the first to be the subject of serious study, as they have long been associated with unpleasant physical sensation and mechanical failure; it is in this range that measurements of propeller vibration stresses lie, since few, if any, aircraft engines produce vibration orders of serious magnitude outside this range.

The third range mentioned is of increasing importance at the present time as it covers the frequencies anticipated in the vibration of gas turbines. Vibration measurements in this field constitute a new branch of the subject and present many added problems to be overcome; initial work suggests that this range covers the more important frequencies.

Analysis of Results

It is not proposed to enter into any detailed description of analysis of oscillograms but to state the requirements that must be met to facilitate the reduction of data from vibration tests.

Whenever possible multiple oscillographs should be employed, enabling simultaneous records to be made from twelve or more test positions on the structure.

This enables a comparison to be drawn between vibration conditions at various points on the structure without the risk of test conditions changing; this may easily happen if single records are made in succession from separate strain gauges or vibrographs.

If, as is often the case, the number of test positions exceeds the number of available oscillograph channels, then successive selections may be made retaining one test source as a "master" and recording it in combination with the other sources. This enables a check to be kept of operating conditions and any changes may be noted and the appropriate action taken.

Regarding the nature of the oscillograph records, these should embody a time standard marking of some kind, and if the records are of vibrations in rotating parts (or in parts of a machine embodying rotational members) it is frequently of use to have a revolution marking device in addition to the time marker. The time marking is commonly obtained from the A.C. mains supply, which is usually accurate enough for engineering standards, while the revolution marker may conveniently be an electro-magnetic device operated by the passage of a small soft iron armature mounted on a rotating part past a "pick-up" coil mounted at a stationary point. The output from the coil will contain a pulse once per revolution when the machine is operating, and this signal may be fed to the oscillograph via an amplifier.

A method of time marking to be employed in the future, and one which has shown promising experimental results, is the use of a gas-discharge lamp to provide the flashing source.

Both 12 and 16-channel amplifier and oscillograph combinations have been operated on propeller and engine vibration recording work with complete success.

The identification of records is facilitated by the inclusion of a serial number which is photographed on to the commencement of each record. The counter which provides this number is operated automatically.

The analysis of records produced on these oscillographs is carried out far more easily than with the earlier 2-4 and 6 channel units, though these still find some use where test requirements are less exacting or where space is severely limited. A typical 12-element oscillograph record is shown in Fig. 3; Fig. 4 shows a part-view of the apparatus used to produce it.

Basic Design of Apparatus

Apparatus for use in the zero and low frequency range divides into two classes; one, for manual operation and for steady stresses only, providing no permanent records of results, the other including apparatus for automatic operation and providing permanent records.

Apparatus for measuring steady stresses is almost invariably based on the Wheatstone bridge principle, elaborations being concerned mainly with the provision for making accurate observations of small changes of resistance, since the changes encountered with strain gauges are seldom more than 2 per cent. of the unstrained resistance value.

When it is not possible to use manually operated steady stress apparatus, or where slowly varying stresses are to be investigated, the apparatus must be in the form of an oscillograph capable of recording zero-frequency signals.

One possible method is to employ a

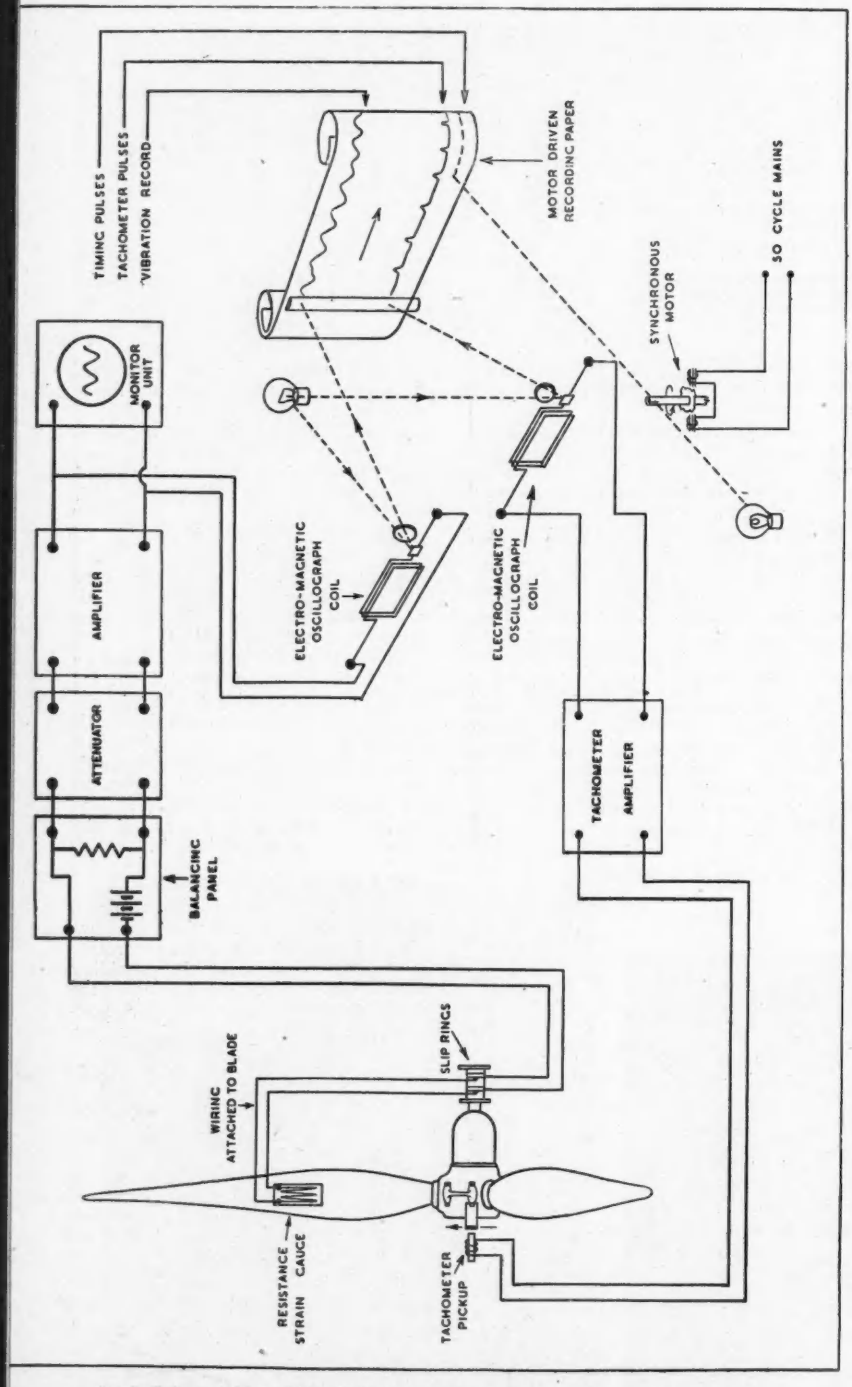


Fig. 7. Schematic view of the method of recording alternating stresses from propeller blades. This method is employed in the apparatus shown in Fig 4, and produces records of the type shown in Fig. 3.

bridge circuit with the strain gauge as one " arm " and to feed the output voltage into a D.C. amplifier; the D.C. amplifier may be used to operate a pen-type low frequency recorder, or a cathode-ray oscillograph may be used.

A method which is, in most cases simpler, and has given very satisfactory results in practice, is to feed the strain gauge bridge circuit with alternating current of a fairly high frequency, say, 400 c/s. (to obtain initial balance of the bridge capacity balancing may be necessary in addition to resistance balance). The output from the bridge will be a small alternating voltage when the strain gauge changes its resistance; this signal, amplified, will provide records on a standard A.C. recording oscillograph, the complication of a D.C. amplifier being avoided. This is a particular advantage with multiple equipment, as a multi-channel D.C. amplifier is generally more bulky and possibly less stable than the A.C. counterpart; at its best a D.C. amplifier is seldom an engineering tool.

The principal methods of measuring stresses in the low frequency range are thus:

(i) The Wheatstone's bridge, or a suitable variant.

(ii) A bridge circuit feeding a D.C. amplifier and pen recorder.

(iii) An A.C. bridge circuit employing a recording oscillograph as the stress indicator.

Fig. 5 shows the methods in schematic form, while Fig. 6 shows a typical 10-circuit stress bridge of the type (i).

For the second (mid-frequency) range from 2 c/s. to 1,500 c/s. (120-90,000 c/min.), the signal from the strain gauge bridge is an alternating one requiring A.C. amplifier practice. It is in this range also that vibrographs of the generator type are employed; since these instruments operate as electro-magnetic velocity type vibration pick-ups, in which the mass is a magnet moving within the turns of a pick-up coil, their output is proportional to the velocity of the vibration; an electric integrating network must be used to give an amplifier input from such a device which is proportional to displacement.

The amplifier used to provide a measureable signal from strain gauge circuits operating in this range must comply with the following requirements:—

(*Continued on p. 76*)

The "Synchrodyne"

A New Type of Radio Receiver for A.M. Signals †

By D. G. TUCKER, Ph.D., A.M.I.E.E.*

A RADIO receiver is generally of either superheterodyne or "straight" type, and in any case effects demodulation of the incoming modulated carrier-wave signal by a process of rectification. Selectivity, or discrimination against unwanted signals, is obtained by means of tuned circuits or band-pass filters inserted in either the radio-frequency or intermediate-frequency sections of the receiver. It is essential to effect the discrimination before demodulation, since otherwise all signals are equally demodulated, and the modulation-frequency output signals become entirely unseparable. It is generally quite difficult to design the selective circuits to give a good discrimination against unwanted signals, while at the same time producing negligible distortion of the wanted signal. Thus selectivity and quality are mutually incompatible requirements of design.

This difficulty can be overcome, and a considerable simplification of circuit detail effected, by a process of demodulation whereby the incoming signal is, without any filtration, demodulated, not by rectification, but by modulation with a frequency equal to its own carrier frequency. The modulation-frequency output of the wanted signal is then obtained correctly, but all other signals become high frequencies relative to the modulation frequency, and can be separated as far as desired by a low-pass filter in the output circuit. A low-pass filter is easily designed to give a very much better pass-band response than a band-pass filter for a given bandwidth and discrimination.[1] Quality reception is now, therefore, quite consistent with high discrimination.

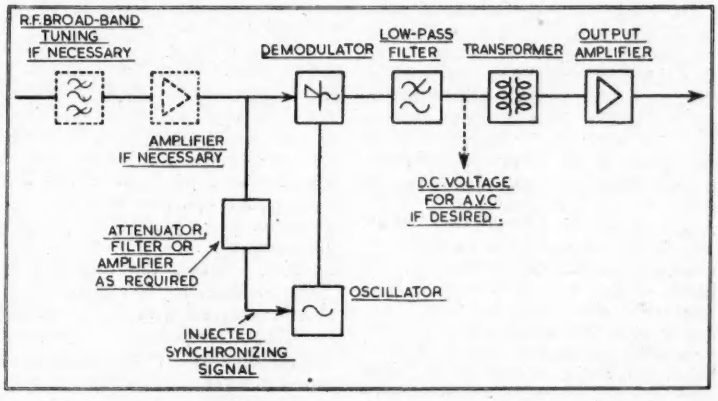


Fig. 1. Schematic diagram of "Synchrodyne" system of reception.

To obtain the frequency for demodulation, which must be the same as the carrier frequency of the wanted signal, it is not possible to use a free oscillator. Any difference between the two frequencies shows up as a beat in the output signal, which is generally intolerable. The method of obtaining the correct frequency is to synchronise[2] the demodulating oscillator to the incoming carrier by injecting some or all of the received signal voltage into the oscillator circuit. Providing the voltage relationships in the circuit are correct in relation to the circuit parameters, the output of the oscillator will be a relatively pure

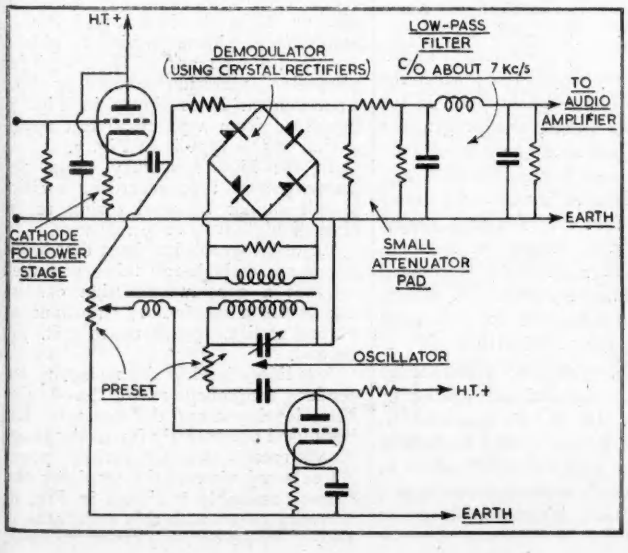


Fig. 2. Details of test circuit.

* P.O. Research Station.
† Prov. Patent.

[1] This point is a function of the dissipation in the filter components. The manner in which dissipation affects the response of low-pass and band-pass filters of Zobel type is discussed fairly fully in the author's paper, "Insertion Loss of Filters," *Wireless Engineer*, 22, p. 62–71, (1945).

[2] For the general theory of synchronization, see (a) D. G. Tucker, "The Synchronization of Oscillators," *Electronic Engineering*, 15, pp. 412 and 457; 16, pp. 26 and 114, 1943. (b) D. G. Tucker, "Forced Oscillations in Oscillator Circuits and the Synchronization of Oscillators," *J. Inst. Elec. Engineers*, 92, Part III, p. 226, (1945).

tone of frequency equal to that of the carrier, with the sideband and other frequencies substantially suppressed. This property of the synchronised oscillator may be described as amplitude discrimination in the nonlinear regenerative circuit, since all frequency components of lower level than the wanted carrier are automatically suppressed by a considerable amount, 30 db. suppression being readily achieved. A full analysis and discussion of this effect is given in another paper.[3] In addition to the amplitude discrimination due to nonlinearity, which is independent of the frequency of the various signal components, there is also, of course, the frequency discrimination due to the tuned regeneration in the oscillator,[3,4] and this is very effective in regard to unwanted signals other than the sidebands of the wanted carrier. It is important that this frequency discrimination should be sufficient to reduce all unwanted signals to a level below that of the wanted carrier, since otherwise the powerful amplitude discrimination effect cannot be utilised. If the unwanted signals are two strong for this, then additional filtration can be provided in the synchronising path before the injection into the oscillator circuit is effected. No restriction of frequency band in this path has any effect on the quality of the output signal.

A block schematic of a typical arrangement is shown in Fig. 1. This is mainly self-explanatory, and is in accordance with the account previously given above. Two additional features are shown, however, viz. :

(1) Very broad-band tuning may be applied to the input, if required, and gauged to the oscillator tuning control. This will have negligible effect on the quality of the demodulated signal, but will prevent strong stations elsewhere in the frequency spectrum from overloading the receiver and thus becoming demodulated by rectification.

(2) A.V.C. may be applied, if desired, by the utilisation of the D.C. component in the output of the demodulator; this component has an amplitude proportional to that of the carrier of the input signal.

[3] D. G. Tucker, "Amplitude Discrimination in Nonlinear Regenerative Circuits," *Wireless Engineer* (to be published soon).

[4] D. G. Tucker, "The Synchronization of Oscillators. Part IV: The Discrimination of a Synchronized Oscillator against Unwanted Signals mixed with the Control Tone." *Electronic Engineering*, 16, p. 114, (1943).

The principle has been adequately tested in practice. A typical test which demonstrates the effectiveness of the method was as follows.—

The B.B.C. Home Service at 877 kc/s. was received at a level of about 0.07 V at the input. A signal generator was set at 867 kc/s. with a 30 per cent. modulation at 400 c/s., and adjusted to roughly the same level, and also applied to the input of the receiver. When the oscillator was tuned approximately to 877 kc/s., with sufficient injected signal to give a synchronised frequency range of about 0.2 per cent. (*i.e.*, about 1 to 2 kc/s.), the broadcast programme was heard with the 400 c/s. tone from the signal generator about 50 or 60 db below the programme level—*i.e.*, almost imperceptible. When the oscillator was tuned to about 867 kc/s., the 400 c/s. tone was heard with the programme just about imperceptible; when the modulation was removed from the signal generator, so that silence should be obtained in the receiver output, the broadcast programme was just perceptible. The circuit used in this test was as shown in Fig. 2; it was more or less the simplest possible.

The operation of the circuit by the user is very simple. The oscillator tuning control is adjusted until the programme is obtained at a suitable volume. The volume of the output depends on the actual working point in the synchronising frequency range, being a maximum when the tuning is set in the middle of this range. When the oscillator is mistuned, a powerful beat note is heard, which makes listening completely impossible; when the oscillator is tuned to *any* point in the synchronising range, the programme quality is equal to the best obtainable, only the volume being affected. *The receiver is thus either correctly tuned or not tuned at all; distorted output is impossible.* This is an immense advantage over ordinary receivers, where mistuning for control of volume is commonly met, with its associated frequency response distortion.

The author wishes to acknowledge the useful suggestions made by Messrs. W. H. B. Cooper, E. R. Hoare, J. F. Ridgeway and F. Scowen in connexion with the development of the new method; most of these suggestions have been incorporated in the above account.

Vibration Measurement Laboratory

(*Continued from p.* 73)

(i) Frequency response to be uniform over the whole frequency range.
(ii) Phase shift must be negligible over the same range.
(iii) Sufficient gain to enable an input signal of 2 mV to provide an output sufficient to load fully the galvanometer element employed in the recording oscillograph.
(iv) An extremely low hum level under all conditions.
(v) The lowest possible value of harmonic distortion.
(vi) Stability.
(vii) Fairly modest power requirements.

An amplifier has been developed which satisfies these conditions and is also extremely compact. It includes an integrating network which can be switched out of circuit when strain gauges are being used as the recording source.

A ladder-type input attenuator is included to limit the input voltage in order that a damaging output power may not be applied to the galvanometer in the oscillograph.

The signal may be monitored by the operator on a 1½ in. cathode-ray tube whose Y-plates are fed from the anodes of the last voltage amplifying stage.

These amplifiers are employed in conjunction with a 12 or 16-element recording oscillograph having moving coil and mirror type galvanometer units. A light source is reflected as a small spot on the recording paper from each galvanometer, while a similar light is interrupted by a synchronous shutter device to give a 50 c/s. timing mark. When used for propeller vibration recording the arrangement is as shown in Fig. 7. A record from a practical test application of this type is in Fig. 3.

In the high frequency range the galvanometer type recording oscillograph cannot be used owing to its limited high frequency response.

An oscillograph has been developed using six cathode-ray tubes arranged so that a continuous-motion camera can obtain a satisfactory simultaneous record at film speeds up to 9 ft. per second.

Amplifiers having the necessary extended frequency range have also been developed and the apparatus has been used successfully for strain gauge measurements on gas turbine parts. An external view of the amplifier and camera assembly is shown in Fig. 8; a record taken with this apparatus in Fig. 9. *Part 2 will appear next month.*

A Transmission Measuring Set for 0.1 to 11c/s

By J. E. BRYDEN, A.M.Brit.I.R.E., Grad.I.E.E.

WITH the advance of biological and servo apparatus very low-frequency circuits are becoming more common. Usually the transmission characteristics of these circuits are important and instruments are required for making measurements of phase shift and attenuation at suitable frequencies.

A transmission measuring set may be divided into the following units:

A. Sending unit.
   (i) The frequency generating circuit.
   (ii) The output circuit.
B. Receiving unit.
   (i) The attenuation measuring circuit.
   (ii) The phase comparison circuit.
C. Power unit.

For very low frequencies the instrument may be either electromechanical or electronic, and for some purposes a mixture of principles may be advantageous. Attenuation and phase shift may be measured by comparing the input and output voltages. This presumes known sending, transmission and receiving circuit impedances. In order to avoid causing unwanted distortion in the

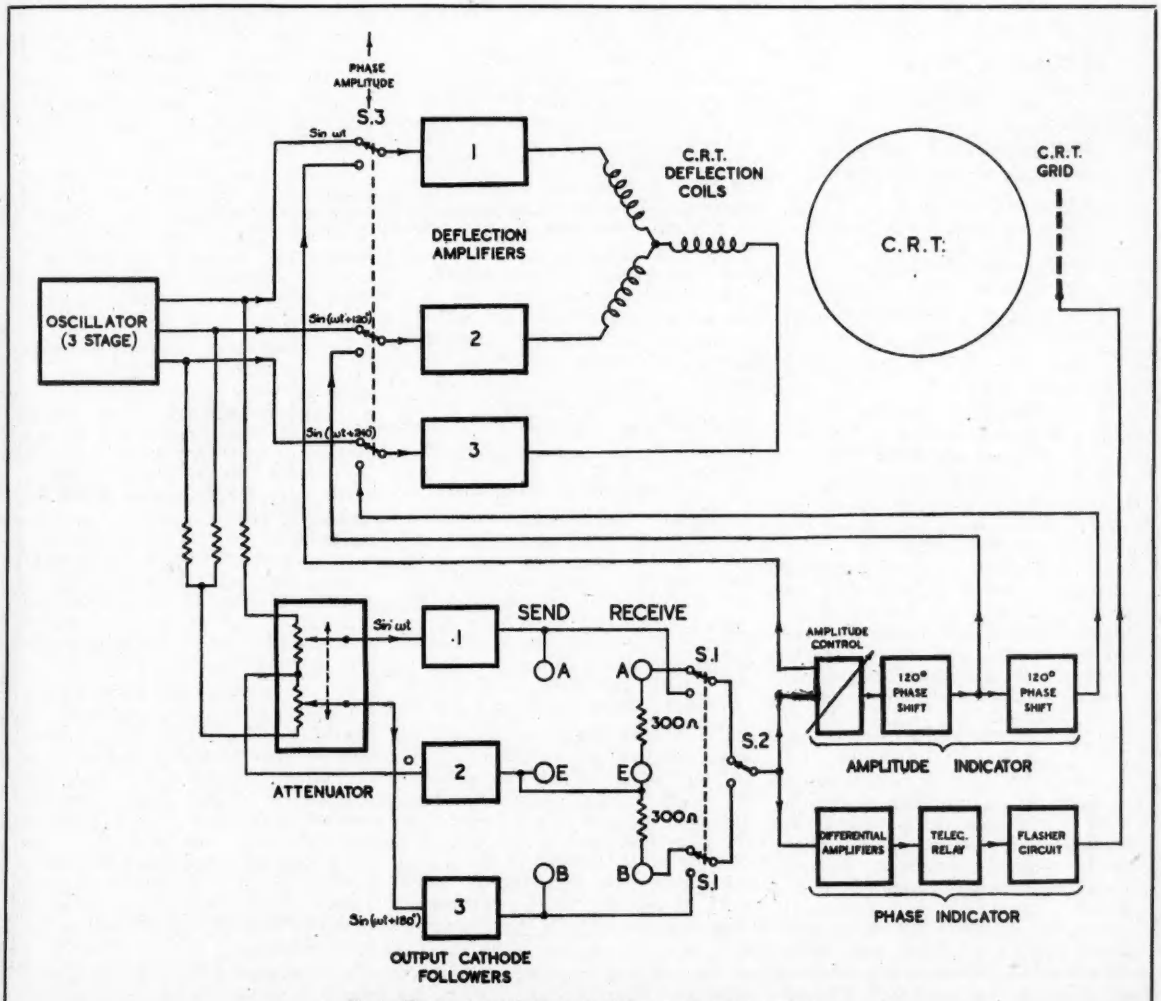


Fig. 1. Block schematic diagram of the complete instrument.

* G.E.C. Research Laboratories, late Military College of Science.

circuit-under-test it is desirable to keep power levels low. For this reason the output from the sending unit should be limited to about two volts when applied to circuits with a characteristic impedance of 600 ohms.

General Description

The instrument to be described is entirely electronic and a trial model has been constructed to comply with the following specification:

Frequency:

Range, 0.1 to 11 c/s. in 0.1. c/s. steps.

Accuracy, ± 3 per cent. over the entire range.

Loss:

Range, 0. to 12 db.

Accuracy, not less than ± 0.5 db.

Phase:

Shift, 0° to 360°.

Accuracy, ± 5°.

Sending impedance:

Not greater than 300 ohms.

Receiving impedance:

300 + 300 ohm ± 1 per cent.

Balanced and unbalanced transmission circuits may be tested.

Balanced circuits may be checked for symmetry.

Gain of a transmission circuit may be measured with the addition of an external attenuator.

A block schematic diagram is given in Fig. 1. An oscillator with adjustable frequency has a three-phase output which is taken through a resistance network to a balanced variable attenuator which provides an in-phase and an anti-phase voltage, together with a neutral point. These are connected to three similar cathode follower stages, which provide low impedance sources for the SEND terminals, A, E and B. A cathode-ray tube is used as an indicator for phase shift and loss measurements, in both cases the beam is deflected to produce a circular trace of the same periodicity as the oscillator frequency. Three-phase electro-magnetic deflection is used, each coil being supplied by a separate amplifier. For phase-shift measurements the output of the oscillator is connected to the input of the deflection amplifiers; this produces a circular timebase close to a rotatable scale which is calibrated in degrees and mounted near the periphery of the cathode ray tube screen. The beam is normally suppressed and is only released over a small arc while the voltage at the input to the phase indicator unit is passing through zero. For loss measurements the single phase voltage appearing at the input to the amplitude indicator unit is converted into three phase and then fed to the deflection amplifiers. The circular trace produced has a radius proportional to the input voltage. The receiving circuits may be connected between either the A and E terminals or the B and E terminals. The procedure for carrying out a test on a circuit connected between the SEND and RECEIVE terminals is illustrated by Figure 2. The steps taken are as follows:

(A) With the attenuator set to 0 db., the indicator units connected to the SEND terminals and the deflection amplifiers connected to the output of the amplitude indicator, the AMPLITUDE control is adjusted until the trace is coincident with a datum circle engraved on a window mounted close to the cathode ray tube screen.

(B) The deflection amplifiers are fed from the output of the oscillator unit. The indicator units are connected to the SEND terminals and the output of the "flasher" to the grid of the cathode-ray tube. A small patch of the circular trace will be brightened as the alternating voltage passes from a small positive to a small negative value. The phase scale is rotated until the zero mark is coincident with the onset of the flash.

(C) With the indicator units connected to the RECEIVE terminals and the deflection amplifiers connected to the output of the amplitude indicator, the attenuator is adjusted for the trace to be coincident with the datum circle. The attenuator is calibrated in db. and now indicates the loss of the circuit connected between the SEND and RECEIVE terminals.

(D) The deflection amplifiers are again fed from the output of the oscillator unit. The indicator units are connected to the RECEIVE terminals and the output of the "flasher" to the grid of the cathode ray tube. The position of the bright patch against the phase scale indicates the phase shift through the circuit-under-test.

In order to check balanced circuits for symmetry and to facilitate tests on unbalanced circuits, the transmission measurements for the A and B lines are made separately. In the case of a balanced circuit, a balanced source and load is applied during both the A and B line tests.

Principles

Method of Measurement.—This is illustrated in Figure 2. The advantages are as follows:—

(A) The loss is measured by comparison with a calibrated attenuator. The indicator acts only as a comparison device.

(B) Phase is indicated at one level. This is desirable as the phase indication is slightly affected by changes in amplitude.

(C) For a given maximum sensitivity of the amplitude indicator, the circuit-under-test is operated with the lowest input level. This minimises the production of harmonics due to non-linearity of this circuit.

(D) The attenuator is also available for providing various output levels.

(E) Only one reference mark is required on the amplitude indicator.

Amplitude Indication.—At frequencies below 1 c/s this cannot be obtained by conventional methods. Normal A.C. meters fluctuate at the input frequency or twice the input frequency.

The peak valve voltmeter can give an almost steady reading at the expense of sluggish indication. As it is required to make measurements with an accuracy of 0.5 db, voltage changes of 6 per cent. must be clearly appreciated. At the lowest frequency of 1/10 c/s. the time constant of the smoothing circuit of the valve voltmeter must be sufficiently large to prevent voltage fluctuations greater than 2 per cent. With a full wave rectifier this would require a time constant of 250 seconds and would waste much time in making amplitude adjustments.

If an in-phase and a quadrature component of identical amplitude are available, the sum of their squares will be non-fluctuating and equal to the square of the peak amplitude. The author has successfully used this method, employing valves as square law devices. Alternatively, two electro-dynamometers coupled to one pointer should give satisfactory results. This has not been tried as the device would be too insensitive for most purposes.

A method with similar fundamentals, which has proved very satisfactory, uses a cathode ray tube with a circular trace of radius proportional

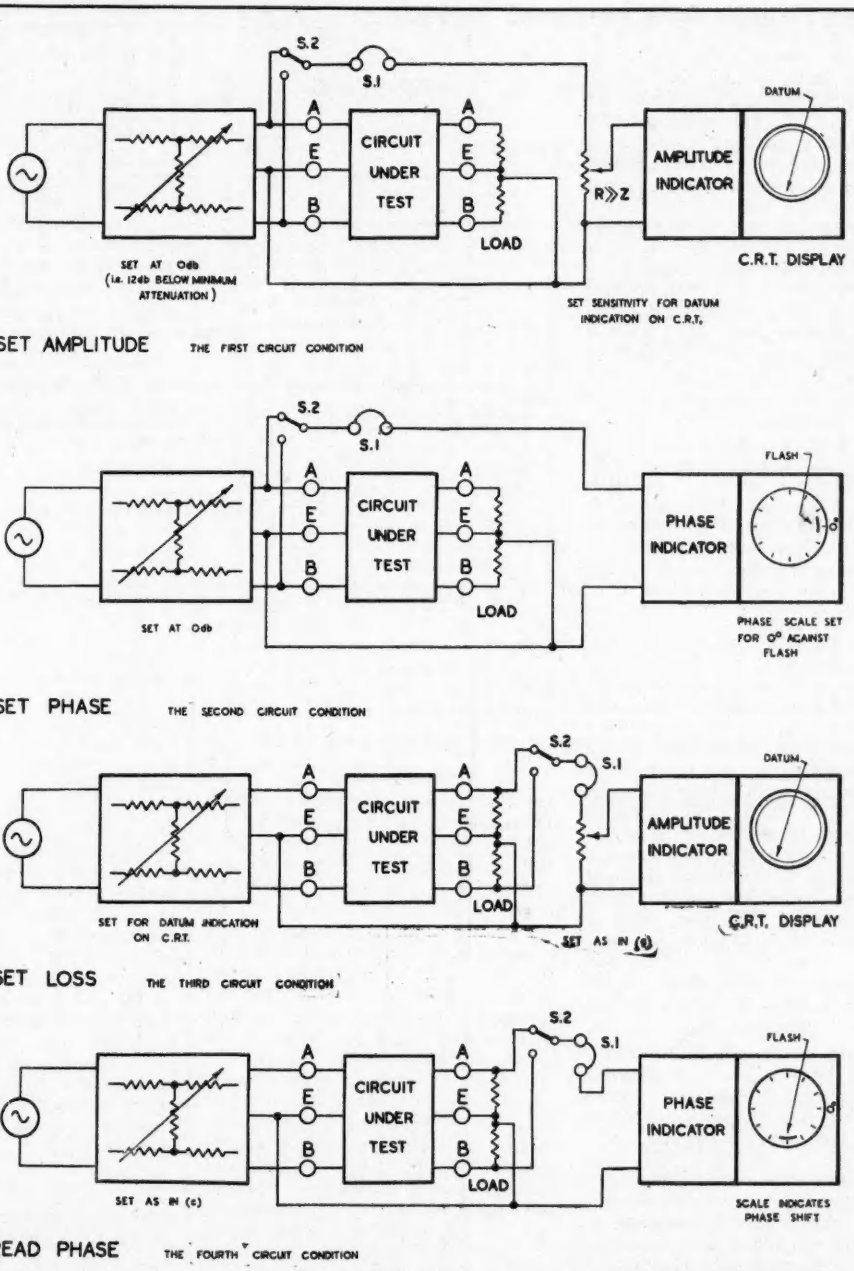


Fig. 2. Illustrating the procedure for measurements. S1 is not shown in its true position. Z is the load impedance.

to the amplitude of the applied voltage. The circular trace is produced by a three-phase electro-magnetic system and the method of obtaining the three-phase voltages for the deflection amplifiers is shown schematically in Figure 3(a). In order to estimate the advantage of this system over one employing smoothing circuits it is necessary to consider the time taken for the spot to settle down to its steady-state-circular-deflection

after a change of amplitude has been made. For convenience, the amplitude will be suddenly changed from zero to a finite value; this corresponds to the closing of the switch in Figure 3(a). The first terms are the steady state alternating components required to produce a circular deflection. The other terms are the transient components which will deflect the spot from its true circular path. The values for α giving the minimum and maximum transient components are 30° and 120°, respectively. Figure 3(b) shows graphs of the percentage off-true-radius error plotted against time expressed as a part of periodicity, for these two values of α. With the instrument operating at 1/10 c/s. the worst condition brought about by a sudden increase of amplitude would settle down to a negligible error within 7 seconds. In practice, when an adjustment is being made there is seldom more than an effective change of E/10, and the indication appears almost instantaneous to the operator, who can appreciate when the circuit is steady.

Phase Indication.—A reference circular deflection is provided by the three-phase output of the oscillator unit. The phase indicator unit must provide a positive pulse for releasing the beam of the cathode-ray tube at a specific point of the cycle of an alternating voltage applied to the input. This pulse should occupy about 1/50th of the period of oscillation. The most easily identified value of a sinusoidal variation is zero, where the rate of change is a maximum. As the indication must be satisfactory for a frequency ratio of 100 to 1, some attempt must be made to maintain the duration of the brightening pulse inversely proportional to frequency.

These essentials can most easily be provided by a high-speed polarised relay arranged to cause a voltage pulse while the tongue is in transit. The Type 299 telegraph relay is suitable. It has six coils which can be arranged as a centre tapped 950 ohm winding, and the tongue will change from one contact to the other with a reversal of 1/5 mA through this winding. At frequencies above 5 c/s. the inertia of the tongue causes the transit time to be extended with a consequential increase in the duration of the brightening pulse, but this introduces no additional error. The sensitivity of the relay is increased by a differential amplifier in order to

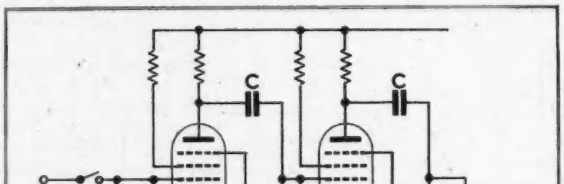
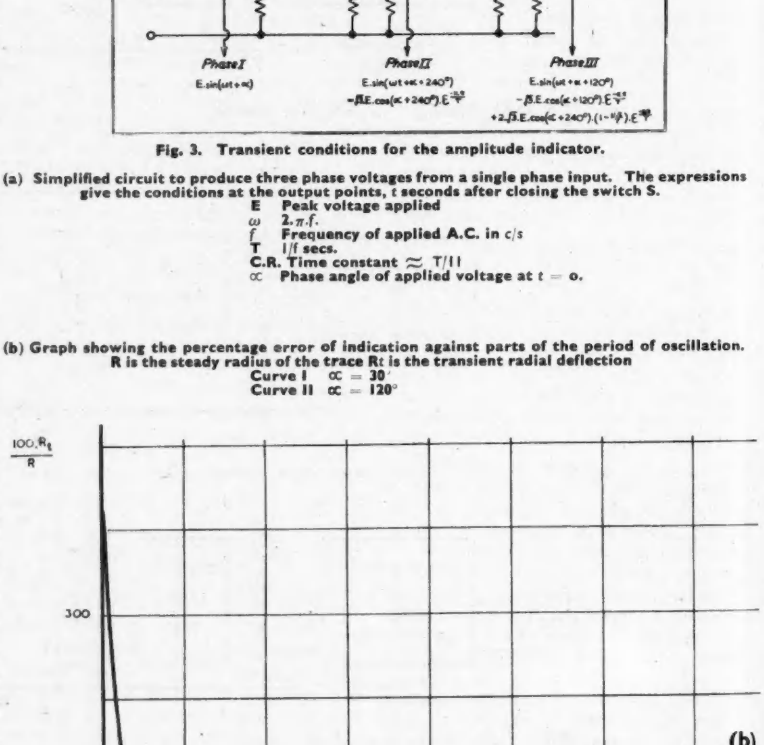


Fig. 3. Transient conditions for the amplitude indicator.

(a) Simplified circuit to produce three phase voltages from a single phase input. The expressions give the conditions at the output points, t seconds after closing the switch S.
E Peak voltage applied
ω 2.π.f.
f Frequency of applied A.C. in c/s
T 1/f secs.
C.R. Time constant ≃ T/11
α Phase angle of applied voltage at t = 0.

(b) Graph showing the percentage error of indication against parts of the period of oscillation. R is the steady radius of the trace Rt is the transient radial deflection
Curve I α = 30°
Curve II α = 120°



obtain reliable operation with the comparatively small output from the circuit-under-test. As an alternating voltage has two zeros per cycle, and only one pulse per cycle is required, it is necessary to introduce a circuit which will provide a positive pulse only when the tongue changes from the mark to the space contact. This is described in detail later. The accuracy of indication will be reduced if the circuit-under-test produces large harmonics. Such a condition will be apparent when making amplitude measurements, as a circular trace will not be produced.

The Display Unit.—A single beam electrostatically focused cathode-ray tube with a screen having long afterglow characteristics and a diameter of about 5 in. is ideal. Owing to factors other than design requirements, a Cossor type 09J tube was used in this experimental model, it is a double beam tube with a short afterglow screen. The results are satisfactory. The deflection sensitivity of a cathode-ray tube increases with a reduction in anode voltages. A change in sensitivity will cause a change in radius of the circular trace. If the variation occurs after the AMPLITUDE control has been adjusted, but before the attenuator is set to compensate for the loss of the circuit-under-test, it will result in the attenuator being incorrectly set. With electrostatic deflection the fractional change in supply voltage and the fractional deflection errors would be equal. Electromagnetic deflection is used, as a change in supply voltage will cause approximately half the error in deflection. As the frequency will be less than 11 c/s., large deflector coils can be used without introducing attenuation distortion. A single stage of amplification gives adequate sensitivity. Excluding the use of shift fields for compensating the effect of the steady anode currents of the valve amplifiers, three phase electromagnetic deflection requires the least number of valves for avoiding the effect of the D.C. component.

Compared with the usual practice of space-quadrature-deflection-fields there are two further advantages. An oscillator giving a three phase output is more convenient than one providing balanced quadrature voltages and the presence of harmonics introduces less error in the required circular deflection.

The technical description of the apparatus will be given in next month's issue.

Valve and Circuit Noise in High Gain Amplifiers

Factors Affecting the Choice of Valve for Input Stage

By H. W. SHIPTON*

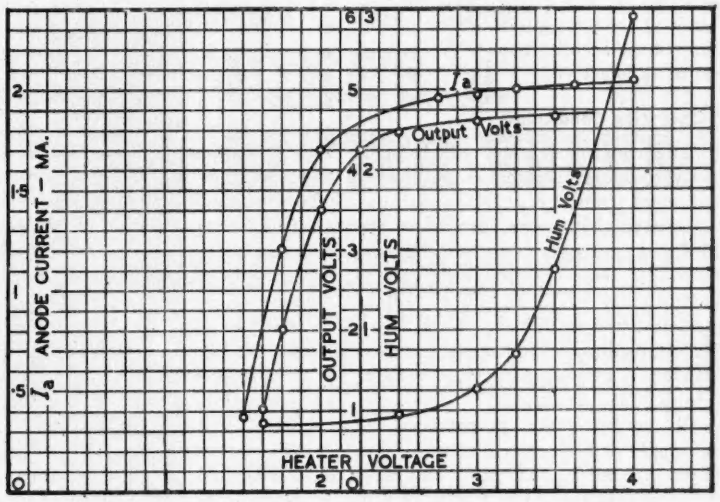


Fig. 1. Curves showing variation of characteristics with heater voltage in triode.

THE importance of maintaining a high signal noise ratio in the input stages of amplifiers for electro-biology and similar applications has been stressed by all workers in this field. A number of special circuits have been described[1] which give a high degree of discrimination against unwanted extraneous signals but careful design is necessary if the hum and noise developed in the stage itself are to be kept to reasonable proportions. The methods by which a low level of circuit noise is achieved are too well known to merit repetition here, and it is sufficient merely to re-emphasise the importance of careful selection of such components as batteries, switches, resistors and other components. The factors influencing the choice of component values, valve types and operating conditions are more varied and it is hoped that the following observations, made during the design of a high gain E.E.G. amplifier, will be of service to those who contemplate the construction of this type of equipment.

* Burden Neurological Institute, Bristol.

Choice of Suitable Valve Types

Triode valves are almost universally used in the input stage and the voltage gain is usually restricted to about 15 or 20. The valve chosen should have as many of the following desiderata as possible.

(a) A high value of g_m.

(b) A "clean" electrode assembly with adequate means of preventing undue rise in grid and anode temperatures.

(c) Low heater wattage and a substantially non-inductive heater.

(d) Freedom from microphony.

Typically, the Mazda V.312 has been found very suitable for most biological work, although it is usually necessary to select individual specimens from a batch if the noise level is to be kept low under stringent conditions. It should be noted that the so-called "white" noise tends to diminish after a running-in period and much labour can be avoided if the heaters of new valves are allowed to run at their normal temperature.

for a period of, say, 24 hours before selection tests are made. Experiments have been made on valves which were initially designed as V.H.F. oscillators (*i.e.*, the V.R. 137, etc.) and, while they perform exceptionally well in most respects, they are microphonic under conditions of low anode and grid dissipation and very elaborate anti-vibration mountings must be used if they are to perform satisfactorily.

Operating Conditions

The conditions under which input valves should operate are the subject of some controversy. Dawson[2] has suggested that anode currents of the order of 100 μA should be used, and it would seem that provided gain is not unduly sacrificed by so doing, lowering the anode current will result in a worthwhile reduction in spontaneous noise voltages. Nelson[3] states that the apparent noise level will be inversely proportional to $gm/\sqrt{I_a}$ and experimentally this has been found to be true. He also suggests that shot effect is more pronounced when the negative grid bias is greater than the usual value. Many workers consider that only D.C. should be used to heat the input stages and use either batteries or a rectified mains supply as a source of L.T. Experience has shown, however, that for most purposes the inconvenience which this entails is not justified. Provided that all heater leads are effectively screened and run as far away as possible from grid leads (valves having top grid caps facilitate a suitable layout) and that electrostatic screening is employed in the mains transformer, raw A.C. can safely be used as a heater supply. A separate secondary winding should be used for each amplifier channel to facilitate balancing. Reference to Fig. 1 will show that it is desirable to use less than the rated value of heater voltage. The heater current should be sufficient to cause a superfluity of electrons to be liberated from the cathode or shot effect is likely to be very pronounced; in input stages, however, a space charge forms at quite a low cathode temperature as the anode current is small. Any substantial increase in heater current will cause the cathode-anode electron stream to be modulated at mains frequency due to the increased E.M. effect, the lowering of the heater-cathode insulation resistance, or emission from the heating element itself. A curve of the type of Fig. 1 should be plotted during the design of the stage in order that the permissible limits of heater voltage may be determined. For a V. 312 under average anode current conditions 2.8 volts is a useful optimum, the heater current being then of the order of 500 mA.

Any remaining modulation of the electron stream due to heater emission can be eliminated by biasing the heater with respect to the cathode. Either positive or negative bias can be used as convenient. Biasing the heater by about 40 V positive will effectively prevent any heater-cathode current, while a similar amount of negative voltage will cause the heater - cathode current to reach saturation and thus not be subject to modulation by the heater supply. It should be borne in mind in deciding the polarity of the heater bias that in amplifiers using a bias battery in series with the cathode resistor the cathode is some 70 V negative to ground when the equipment is switched off and an additional 40 V will impose a considerable strain on the cathode heater insulation if the heater is made positive. It is therefore suggested that the centre point on the "humdinger" be returned to a suitable tapping on the cathode bias battery.

Conclusion

Careful selection of valves and components, coupled with experimental work to determine optimum circuit performance will result in an amplifier which will be free from the annoying "artefacts" which are so often due to self-generated input stage noise.

[2] Adrain and Matthews, *Journ. Physiol*, 81, pp. 286 and 440, 1934. Parr and Walter, *Jour. I.E.E.*, 90, 129, *et al.*

[3] Dawson G. D., Private Communication.

[4] Nelson J. R., "Noise in Vacuum Tubes," *Raytheon Production Corporation Bulletin.* No. 53.

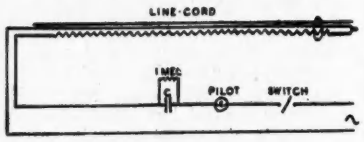
Domestic De-Icing

Although strictly not electronic, this application of radio components to the solution of present-day domestic troubles is sufficiently novel and timely to warrant space!—ED.

Fool-proof anti-freeze measures can be applied to the average domestic water system at very low cost by using line cord—the voltage-dropping resistor cable commonly used with midget radio receivers.

The best quality line cord, rated to carry 0.3 amps., is strapped on the underside of the water pipes with insulating tape, and the felt lagging replaced over the pipe.

The resistance of the cord is 60 ohms per foot, and the current is limited to 0.2 amps. or less in the interests of safety and long life. The voltage is obtained from the mains supply, any excess being dropped by a series capacitor (*see* Figure).



CIRCUIT- DOMESTIC DE-ICER.

Since the voltage across the capacitor is in quadrature with the voltage across the line cord, the value of the capacitor can be calculated as follows:

Voltage required for 10 ft. of pipe:

$$10 \times 60 \times 0.2 = 120$$

Voltage to be dropped from 230 v. mains:

$$\sqrt{230^2 - 120^2} = 196 \text{ v.}$$

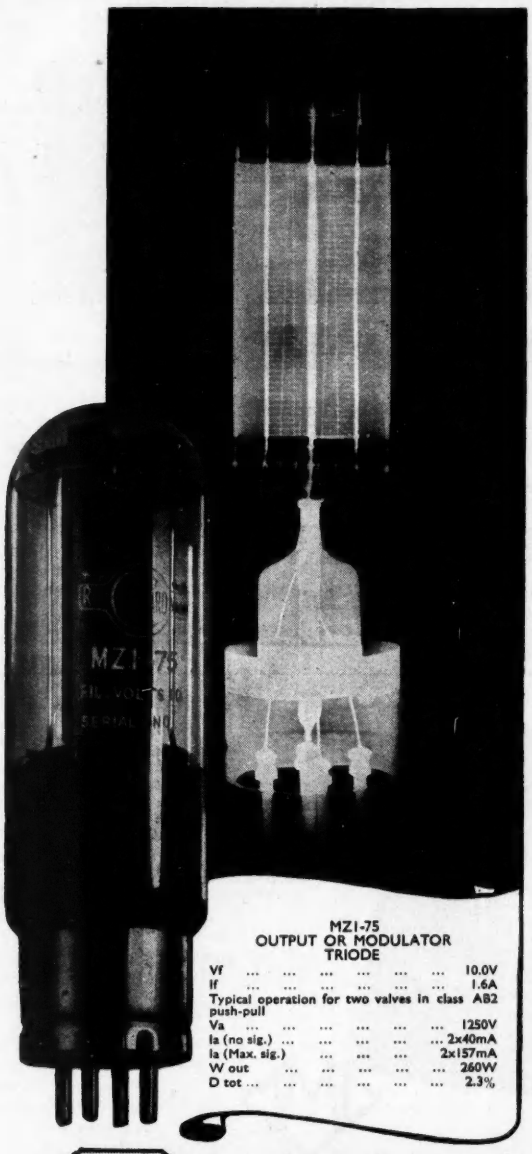
Capacity in μF.

$$= \frac{10^6 \times I}{2\pi f.\ V_c} = 3.25 \text{ approx.}$$

It is important that the capacitor conforms to the standard laid lown in B.S.I. 415—1941. The terminals should be suitably protected and it should be shunted by a resistor of 1.0 megohms., as shown.

If it is desired to have an indication that the heat is on, a pilot lamp (0.3 a. dial light) is included in the circuit. The bulb also acts as a fuse, and no trouble has been experienced from surges on switching on.

J. S. WORTHINGTON.


MZ1-75
OUTPUT OR MODULATOR
TRIODE
Vf 10.0V
If 1.6A
Typical operation for two valves in class AB2 push-pull
Va 1250V
Ia (no sig.) 2x40mA
Ia (Max. sig.) 2x157mA
W out 260W
D tot 2.3%

For modulation and L.F. amplification

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All things being equal, the real measure of a valve's performance is the length of time it will operate with undiminished efficiency. In this respect the MZ1-75 scores heavily. Like all Mullard transmitting and industrial valves, it has been designed with an eye to cost per life-hour.

Modern manufacturing methods ensure its reliability and offer the additional advantage that all valves of the same type are characteristically consistent. The long-life, oxide-coated filament is unaffected by fluctuations in the mains supply, and also permits operation at an economical anode voltage.

A glance at the data panel with these factors in mind will explain why the MZ1-75 wins the approval of communications engineers who want a better valve for modulation and L.F. Amplification.

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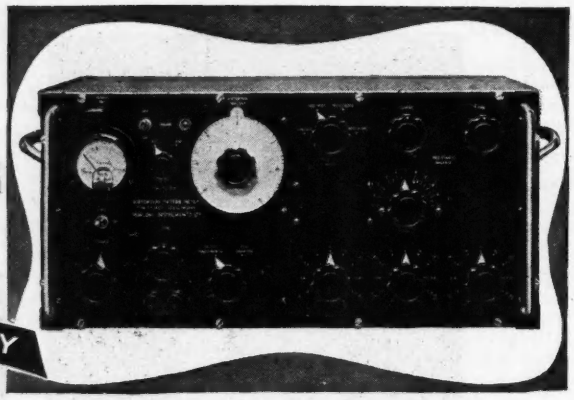

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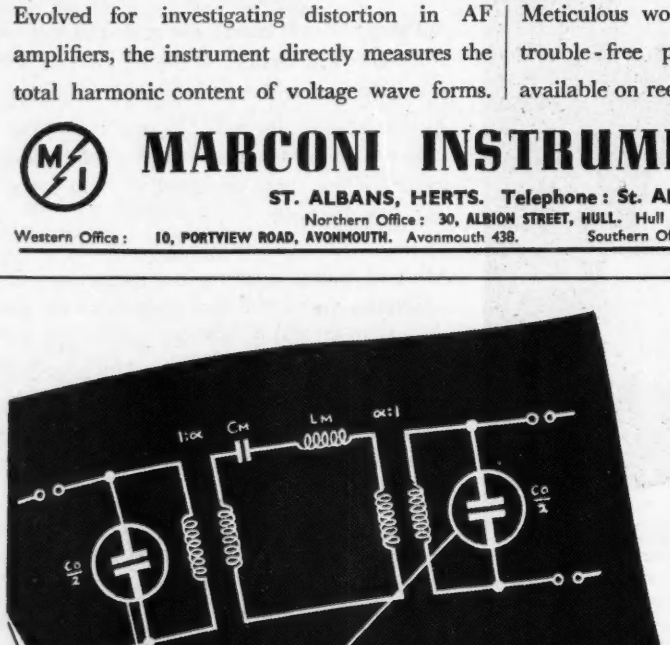

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The Design of Tuned Transformers—Part I

By F. G. CLIFFORD*

Three methods of designing tuned transformers are discussed. These are (1) to transform the circuit until it has the same configuration as a ladder filter of which the design data is known ; (2) to evolve design data from a consideration of the impedances presented by one pair of terminals when the other pair is open-circuited and short-circuited and (3) to apply Bartlett's Bisection Theorem and thereby find the equivalent symmetrical lattice network for which the design data may be found simply. Method (3) is a simplification of Method (2) but is applicable only to tuned transformers which are equivalent to a symmetrical T-or-π-section. Examples of the applications of these three methods are given. Design data and characteristics of a number of useful types of low-pass, high-pass and band-pass transformers are tabulated.

1. Introduction

OF the various methods that have been employed in the past few years for the design of tuned transformers, three have proved particularly useful and it is intended to describe and demonstrate these three methods.

Certain types of tuned transformers may be designed with more than one pass band but only the conditions necessary for a single pass band will be considered in detail as this is the usual requirement. Resistive loads are assumed in the design and when in practice, additional reactive components exist in the terminations, it is frequently necessary to include them in the tuning system of the transformer.

The design data and characteristics of a number of the most useful tuned transformers are given together with a reference number system which will be used throughout.

2. Equivalent Networks

When deriving the design data of tuned transformers it is sometimes necessary to use the equivalent networks of the tuned transformer system. Probably the most simple method of deriving the equivalent ladder network is to evolve the equivalent network of the untuned transformer portion and add to this the network of tuning reactances. If the equivalent ladder network may be realised in symmetrical form, the equivalent lattice network may be derived by the use of Bartlett's theorem.[1]

Consider the untuned transformer and the T-network in tandem with a theoretically ideal unity ratio transformer shown in Figs (1) and (2). If the terminals c and d in Fig. (1) and terminals m and n in Fig. (2) are closed with similar impedances and the impedances Z_1 and Z_{11} measured between terminals a and b, and x and y in Figs. (1) and (2) respectively, are identical at any frequency, the transformer and the T-network may be said to possess equivalent impedance characteristics.

If also, when terminals a and b, and x and y in Figs. (1) and (2) are closed with any equal impedances and Z_2 and Z_{22}, measured between terminals c and d, and m and n in Figs. (1) and (2) respectively, are identical at any frequency, the T-network may be said to be the equivalent network of the untuned transformer.

When L_A and L_B are respectively the self-inductances of the primary and secondary windings measured with the other winding open-circuited, and k is the co-efficient of coupling of the untuned transformer shown in Fig. 1, it can be shown[2] that the T-network shown in Fig. 2 is the equivalent network of the transformer when :—

$$L_C = L_A \pm k\sqrt{L_A L_B}$$
$$L_D = L_B \pm k\sqrt{L_A L_B}$$
$$L_E = \mp k\sqrt{L_A L_B} \quad \ldots\ldots\ldots (1)$$

When no electrical connexion is made between the primary and secondary windings of the transformer, either the upper or the lower signs in the above expressions may be used. When a connexion exists between one end of the primary winding and one end of the secondary winding, the ideal unity ratio transformer shown in Fig. 2 may be omitted and the lower signs in the expressions should be employed if the connexion places the windings in series opposition. If the connexion places the windings in series aiding, then the upper signs should be used.

The transformer shown in Fig. 3 is operating between impedance R_1 and R_2 and an equivalent T-network is shown in Fig. 4. If the impedance ratio of the ideal transformer is altered from unity to the value x^2, then in order that the T-network may remain the equivalent network of the transformer, the values of its arms must be modified. It can be shown[3] that the values of the elements of the T-network are as shown in Fig. 5, when the impedance ratio of the ideal transformer is x^2. This is true for any value of x and this fact may be used to transform the T-network into an equivalent L-network if the value of x is so chosen that one of the series elements of the T-network shown in Fig. 5 is equal to zero. The value of x for these conditions may be evaluated in the following manner :—

$$\text{Let } L_A - \frac{k}{x}\sqrt{L_A L_B} = 0$$

$$\therefore x^2 = \frac{k^2 L_B}{L_A} \quad \ldots\ldots\ldots (2)$$

$$\text{or let } \frac{L_B}{x^2} - \frac{k}{x}\sqrt{L_A L_B} = 0$$

$$\therefore x^2 = \frac{L_B}{k^2 L_A} \quad \ldots\ldots\ldots (3)$$

$$\text{When } x^2 = \frac{k^2 L_B}{L_A}$$

Equation 2, the value of the left hand series element of the T-network shown in Fig. 5 is zero and the resulting L-network is as shown in Fig. 6. From Equation (3),

$$\text{when } x^2 = \frac{L_B}{k^2 L_A}$$

the value of the right-hand series element of the T-network is zero and the equivalent L-network is as shown in Fig. 7.

The T-network shown in Fig. 5 may also be transformed into a symmetrical T-network when the value of x is such that the values of both the series elements are equal. The value of x for this condition may be obtained from the following :—

$$\text{Let } L_A - \frac{k}{x}\sqrt{L_A L_B} = \frac{L_B}{x^2} - \frac{k}{x}$$

$$\sqrt{L_A L_B} \quad \therefore x^2 = \frac{L_B}{L_A} \quad \ldots\ldots\ldots (4)$$

$$\text{When } x^2 = \frac{L_B}{L_A}$$

Equation 4, the resulting equivalent network is the symmetrical T shown in Fig. 8. It can be shown[5] that this symmetrical T-network is equivalent to the symmetrical π-network shown in Fig. 9.

It should be noted that all the networks in Figs. 4 to 9 are equivalent

* P.O. Research Station, Dollis Hill.

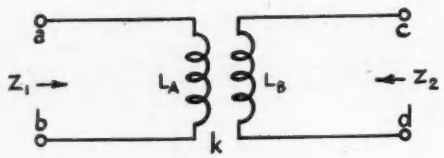


FIG. 1.

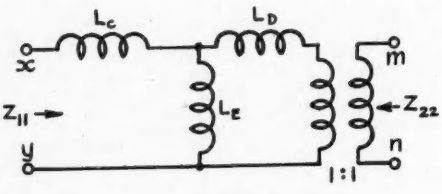


FIG. 2.

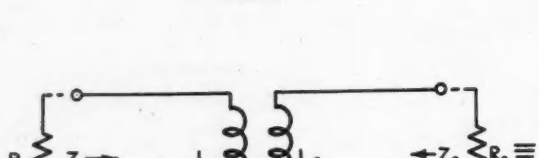


FIG. 3.

FIG. 4.

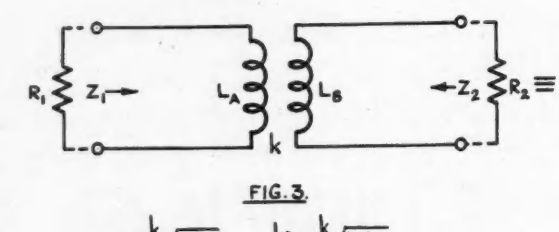


FIG. 5.

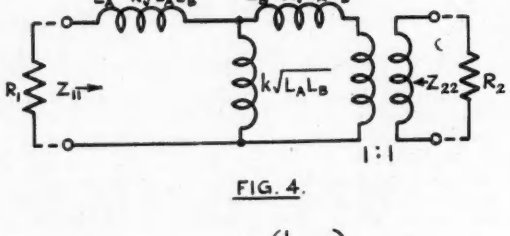
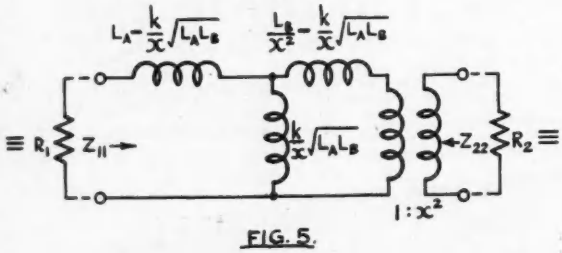


FIG. 6.



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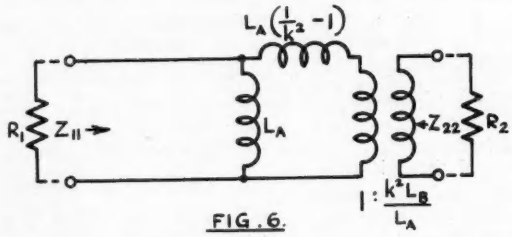


FIG. 8.

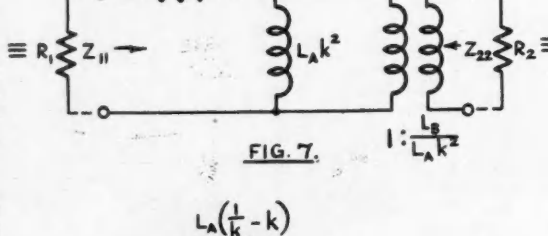


FIG. 9.

to the untuned transformer shown in Fig. 3 and hence possess similar frequency-insertion loss characteristics.

3. Methods of Design

Of the methods which may be employed to derive the design data of various types of tuned transformers, three are in general use. It is proposed to describe these three methods and demonstrate their use by applying each in turn to the design of a specific type of tuned transformer.

Method 1 which is described in Section 3.1 employs the equivalent ladder filter network of the tuned transformer and utilises the design data of that filter network.

Method 2 employs the fundamental method of filter network design which uses the open and short circuit impedances of the tuned transformer network. This method is described in Section 3.2.

In Section 3.3 a description of Method 3 is given. In this method the equivalent lattice network of the tuned transformer is obtained by means of Bartlett's Theorem and the design data for the lattice network is obtained in a manner similar to that used in Method 2. As explained in Section 3.3, Method 3 can only be used for certain types of tuned transformers.

Methods 2 and 3 may often be simplified by the use of Foster's Theorem and the use of this theorem is demonstrated in Section 3.4.

3.1 Method 1

A large amount of information on the design of electric wave filters is now available and one method of evolving the design data of any tuned transformer into an equivalent electric wave filter section and use the design formulae appropriate to that filter section[3]. The notation due to Shea[4] will be employed in the following analysis.

To demonstrate this method of design, the design data of a tuned transformer of the type which comprises two mutually coupled inductors with a capacitance connected in parallel with each winding[3] will now be evolved. This type has been designated Type 2A in this article, and is shown operating between two resistive terminals R_1 and R_2 in Fig. 10. The most suitable equivalent network for use in this case is based on that shown in Fig. 9 and the full equivalent network of this tuned transformer, Fig. 10, is shown in Fig. 11. When the condenser C_B and the load resistance R_2 are moved to the other side of the ideal transformer and the ideal transformer is removed, the network shown in Fig. 12 is obtained. This is a band-pass π-section filter type III_3[5], operating between the resistive loads R_1 and $\frac{R_2L_A}{L_B}$. This filter is shown in symbolic form in Fig. 13 and since mid-shunt termination is employed:—

$$L_1 = L_A \frac{(1-k^2)}{k}$$

$$L_2 = L_A \frac{(1+k)}{2}$$

$$C_2 = 2C_A \quad \ldots\ldots\ldots\ldots (5)$$

The design data for this filter section[5] is as follows:—

$$L_1 = \frac{R_1}{\pi(f_1+f_2)}$$

$$L_2 = \frac{(f_2-f_1)R_1}{4\pi f_1^2}$$

$$C_2 = \frac{1}{\pi(f_2-f_1)R_1} \quad \ldots (6)$$

where f_1 and f_2 are the lower and upper frequency limits of free transmission, *i.e.*, the cut-off frequencies.

This type of filter is a symmetrical π-section and in order that the network shown in Fig. 12 shall be equivalent to this filter section the two resistive terminations R_1 and $\frac{R_2L_A}{L_B}$ and also the two capacitances C_A and $\frac{C_BL_B}{L_A}$ must be equal in value.

$$\therefore \frac{R_1}{R_2} = \frac{L_A}{L_B} = \frac{C_B}{C_A} \quad \ldots\ldots\ldots\ldots (7)$$

By rearranging Equations (5), (6) and (7) the design data for the tuned transformer may be obtained:—

$$L_A = \frac{f_1^2+f_2^2}{8\pi^2 f_1^2 f_2^2 C_A}$$

$$L_B = \frac{f_1^2+f_2^2}{8\pi^2 f_1^2 f_2^2 C_B}$$

$$C_A = \frac{1}{2\pi(f_2-f_1)R_1}$$

$$C_B = \frac{1}{2\pi(f_2-f_1)R_2}$$

$$\frac{f_2}{f_1} = \sqrt{\frac{1+k}{1-k}} \quad (8)$$

The appropriate design data for any tuned transformer may be derived by the application of this method. In the particular case demonstrated, the equivalent π-network of the form shown in Fig. 9 is used, but when deriving the design data of other types of tuned transformers it may be advantageous to use the equivalent L- or T-networks of the forms shown in Figs. 6, 7 and 8.

Method 1 may be employed without difficulty when the equivalent ladder filter section is simple and the design data of the filter section is known. When the design data of the complete equivalent section is not known (for example, in certain cases when the equivalent filter section comprises two or more types of simple filter sections in tandem), it is necessary to derive the design data for the complete filter section. This complicates the use of Method 1, and Method 2 or 3 may then be employed with advantage.

3.2 Method 2

This may be called the open and short-circuit method. It may be used to obtain the design data for any type of tuned transformer and has the advantage over Method 1 that it is not necessary to know the design formulae applicable to certain types of ladder filter sections.

In any network the image impedance at any one frequency may be calculated from a knowledge of the impedance presented by the network when the far end is open-circuited and short circuited:—

$$Z_o = \sqrt{Z_{oc}\ Z_{sc}} \quad \ldots\ldots\ldots\ldots (9)$$

where Z_o is the image impedance and Z_{oc} and Z_{sc} are the open and short-circuit impedances respectively. If all the elements in the network are pure reactances, then Z_{oc} and Z_{sc} must also be pure reactances. When Z_{oc} and Z_{sc} have the same sign, *i.e.*, both are capacitive or inductive, Z_o is a pure reactance, but when Z_{oc} and Z_{sc} have opposite signs, Z_o is a pure resistance.

It has been shown by many authors (*e.g.*, Shea[6]) that when Z_o is a reactance the network will not transmit power without attenuation, but when Z_o is a resistance it will introduce no attenuation if correctly terminated. The frequency bands over which Z_o is a pure reactance and a pure resistance are said to be stop bands and pass bands respectively.

A transformer, complete with tuning reactances, may be treated in this manner and from a knowledge of the open and short-circuit impedances,

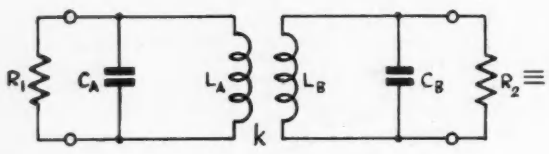


FIG. 10.

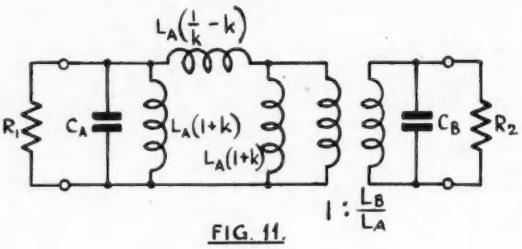


FIG. 11.

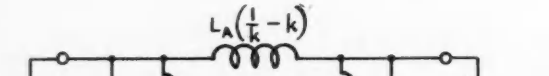


FIG. 12.

FIG. 13.

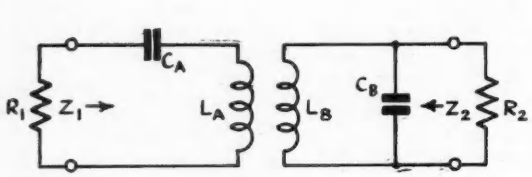


FIG. 14.

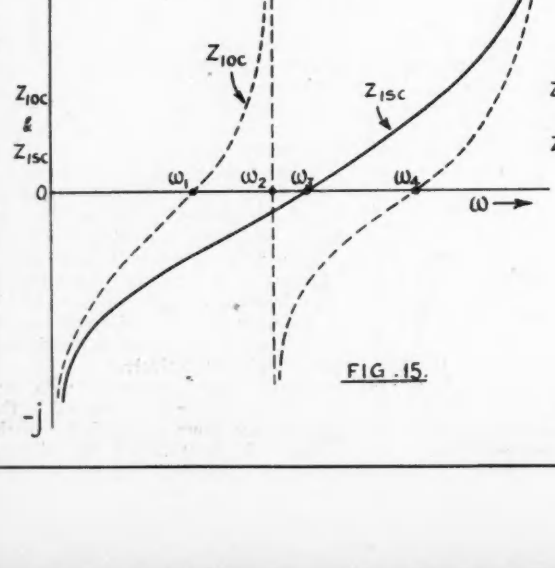


FIG. 15.

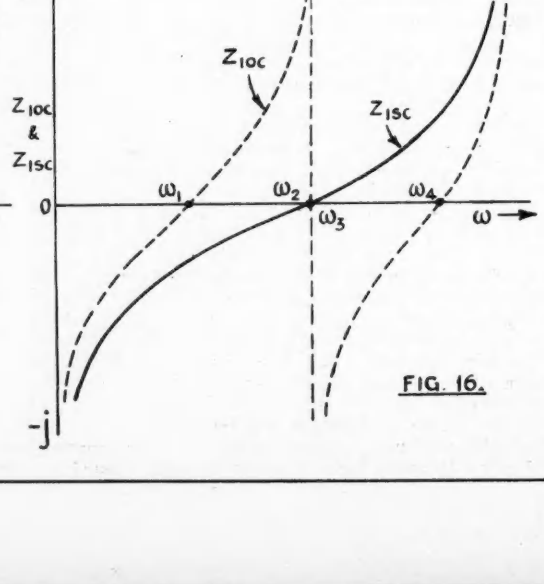


FIG. 16.

the design data may be derived[4]. By way of additional explanation, Method 2 will now be used to derive the design data for a typical type of tuned transformer.

Consider the tuned transformer type 2.C, shown in Fig. 14 operating between two resistances R_1 and R_2. The impedance presented to the resistance R_1 when the value of the resistance R_2 is alternately infinite Z_{1oc} and zero Z_{1sc} is given by :—

$$Z_{1oc} = -j\left[\frac{1 - \omega^2(L_AC_A + L_BC_B) + \omega^4L_AL_BC_AC_B(1 - k^2)}{\omega C_A(1 - \omega^2L_BC_B)}\right] \quad (10)$$

$$Z_{1sc} = j\left[\frac{\omega^2L_AC_A(1 - k^2) - 1}{\omega C_A}\right] \quad (11)$$

where L_A, L_B and C_B are the values of the elements shown in Fig. 14, and k is the coefficient of inductive coupling between the two windings. The open and short-circuit impedance-frequency characteristics are shown in Fig. 15 and the critical frequencies corresponding to ω_1, ω_2, ω_3 and ω_4, at which the impedances are zero or infinite in value, are such that :—

$Z_{1oc} = 0$, at the frequency corresponding to ω_1 or ω_4.

$Z_{1oc} = \infty$, at the frequency corresponding to ω_2.

$Z_{1sc} = 0$, at the frequency corresponding to ω_3.

From an inspection of the relative positions of the characteristics shown in Fig. 15 and from a knowledge of the fact that two impedances have opposite signs in a pass band and similar signs in a stop band, the following information may be obtained :—

Frequency Band	Sign of Z_{1oc}	Sign of Z_{1sc}	Pass or stop band
0 to ω_1	—	—	stop band
ω_1 to ω_2	+	—	pass band
ω_2 to ω_3	—	—	stop band
ω_3 to ω_4	—	+	pass band
ω_4 to ω_{∞}	+	+	stop band

It will be seen that two separate pass bands are present and in order that the required condition of only one pass band is realised it is necessary to modify the values of certain critical frequencies. A single pass band will appear if ω_3 is made equal in value to ω_1 or ω_2 or ω_4, but since it can be shown from Equations (10) and (11) that with real element values ω_3 cannot be equal in value to ω_1 or ω_4, the only solution for one pass band is when ω_3 is equal in value to ω_2. A single pass band will then extend between frequencies corresponding to ω_1 and ω_4 and two stop bands will appear, one below ω_1 and one above ω_4. The relative positions of the open and short-circuit impedance-frequency characteristics will now be as shown in Fig. 16, and at the frequency corresponding to ω_2, Z_{1oc} will be infinite and Z_{1sc} will be zero in value. From Equations (10) and (11) :—

When $Z_{1oc} = \infty$,

$$1 - \omega_2^2L_BC_B = 0 \quad \ldots\ldots (12)$$

and when $Z_{1sc} = 0$

$$1 - \omega_2^2L_AC_A(1 - k^2) = 0 \quad \ldots\ldots (13)$$

$$\therefore L_AC_A(1 - k^2) = L_BC_B \quad \ldots\ldots (14)$$

The impedance Z_{1oc} is zero at the two cut-off frequencies corresponding to ω_1 and ω_4 at the extremities of the pass band. Let the frequencies at which Z_{1oc} is zero correspond to ω_0, then from Equation (10) :—

$$0 = 1 - \omega_0^2L_AC_A - \omega_0^2L_BC_B + \omega_0^4L_AL_BC_AC_B(1 - k^2) \quad (15)$$

from Equation (14)

$$L_AC_A(1 - k^2) = L_BC_B$$

therefore subsituting $L_AC_A(1 - k^2)$ for L_BC_B in Equation (15) :—

$$0 = 1 - \omega_0^2L_AC_A(2 - k^2) + \omega_0^4L_A^2C_A^2(1 - k^2)^2 \quad \ldots\ldots (16)$$

$$\omega_0^2 = \frac{2 - k^2 \pm \sqrt{4k^2 - 3k^4}}{2L_AC_A(1 - k^2)^2}$$

but ω_1 and ω_4 are the lower and upper values of ω_0 :—

$$\therefore \omega_1^2 = \frac{2 - k^2 + \sqrt{4k^2 - 3k^4}}{2L_AC_A(1 - k^2)^2} \quad \ldots\ldots (17)$$

$$\text{and } \omega_4^2 = \frac{2 - k^2 + \sqrt{4k^2 - 3k^4}}{2L_AC_A(1 - k^2)^2} \quad \ldots\ldots (18)$$

Electric wave filters are generally designed to operate into resistive loads which match the image impedance of the filter at the mid-band frequency corresponding to ω_m. In the case of a band-pass filter this mid-band frequency is taken as the geometric mean of the two cut-off frequencies, whereas in the case of low or high-pass filters the mid-band frequency is taken as zero or infinite respectively.

Therefore in this case $\omega_1\omega_4 = \omega_m^2$, and from Equations (17) and (18) :—

$$\omega_m^2 = \frac{1}{L_AC_A(1 - k^2)} \quad \ldots\ldots (19)$$

From Equations (13) and (19) it will be seen that ω_2 is equal to ω_m.

The image impedance Z_{01} may be obtained from Equations (10), (11) and (14), since $Z_{01} = \sqrt{Z_{1oc}Z_{1sc}}$:—

$$\therefore Z_{01} = \ldots (20)$$

$$j\sqrt{\frac{1 - \omega^2L_AC_A(2 - k^2) + \omega^4L_A^2C_A^2(1 - k^2)^2}{\omega^2C_A^2}}$$

The image impedance Z_{m1} at the mid-band frequency is made equal in value to the resistive load R_1 and from Equations (19) and (20) :—

$$Z_{m1} = \frac{k}{\omega_mC_A\sqrt{1 - k^2}} = R_1 \quad \ldots (21)$$

The portion of the design data which has been obtained may now be collected :—

$$R_1 = \frac{k}{\omega_mC_A\sqrt{1 - k^2}},$$

$$\omega_m^2 = \frac{1}{L_BC_B} = \frac{1}{L_AC_A(1 - k^2)},$$

$$\omega_1^2 = \frac{2 - k^2 - \sqrt{4k^2 - 3k^4}}{2L_AC_A(1 - k^2)^2} \text{ and}$$

$$\omega_4^2 = \frac{2 - k^2 + \sqrt{4k^2 - 3k^4}}{2L_AC_A(1 - k^2)^2}$$

The remaining portion of the design data may be obtained from the impedances presented by the tuned transformer shown in Fig. 14 to the resistive load R_2, when the value of the resistive load R_1 is zero and infinite. These impedances are given by :—

$$Z_{2sc} = j\frac{\omega L_B}{1 - \omega^2L_BC_B} \quad \ldots\ldots (22)$$

where Z_{2sc} is the impedance presented to the load R_2 when the far end of the tuned transformer is short-circuited.

From Equations (14), (19) and (22) :

$$Z_{2sc} = j\frac{\omega L_B}{1 - \frac{\omega^2}{\omega_m^2}} \quad \ldots\ldots (24)$$

Secondly, if Z_{2oc} is the impedance presented to R_2 when the far end is open-circuited, we have :

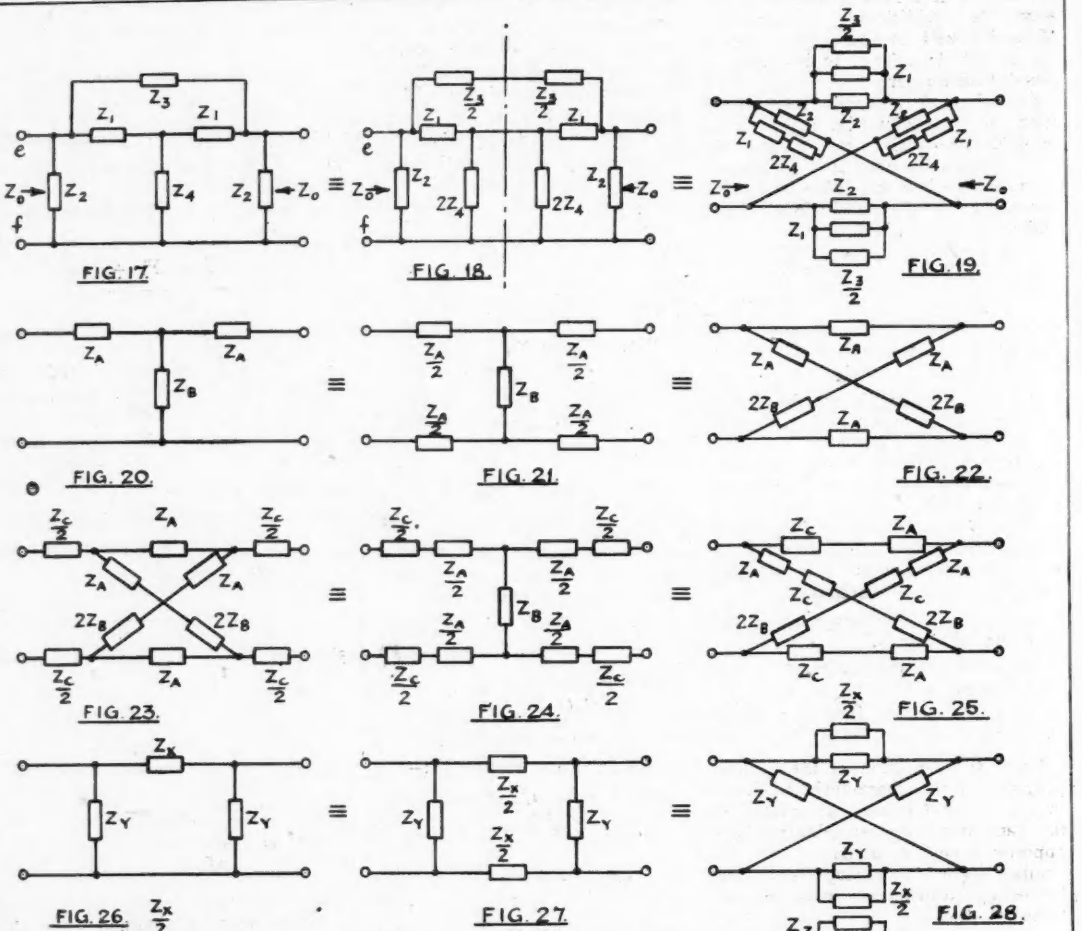


FIG. 17.
FIG. 18.
FIG. 19.
FIG. 20.
FIG. 21.
FIG. 22.
FIG. 23.
FIG. 24.
FIG. 25.
FIG. 26.
FIG. 27.
FIG. 28.
FIG. 29.
FIG. 30.
FIG. 31.
FIG. 32.
FIG. 33.

$$Z_{2oc} = j\frac{\omega L_B\,(1 - \omega^2 L_A C_A\,(1 - k^2))}{1 - \omega^2 L_A C_A - \omega^2 L_B C_B + \omega^4 L_A L_B C_A C_B\,(1 - k^2)} \quad \ldots\ldots (23)$$

and from Equations (14), (19) and (23):

$$Z_{2oc} = j\frac{\omega L_B\left(1 - \frac{\omega_2}{\omega_m^2}\right)}{1 - \frac{\omega^2}{\omega_m^2(1 - k^2)} - \frac{\omega^2}{\omega_m^2} + \frac{\omega^4}{\omega_m^4}}$$

The image impedance Z_{o2} may be obtained from Equations (24) and (25) since $Z_{o2} = \sqrt{Z_{2oc} \cdot Z_{2sc}}$:—

$$Z_{o2} = j\frac{\omega L_B}{\sqrt{1 - \frac{\omega^2}{\omega_m^2(1 - k^2)} - \frac{\omega^2}{\omega_m^2} + \frac{\omega^4}{\omega_m^4}}}$$

The image impedance Z_{m2} at the mid-band frequency, is equal in value to the resistive load R_2, therefore when $\omega = \omega_m$:—

$$Z_{m2} = R_2 = \frac{\omega_m L_B \sqrt{1 - k^2}}{k} \quad \ldots\ldots\ldots (27)$$

This expression completes the design data for tuned transformers type 2.C

In the demonstration of Method 2 the open and short-circuit impedances were given in terms of the element values and the coefficient of inductive coupling. The derivation of the design data may generally be simplified if Foster's Theorem[6] is used and the impedances expressed in terms of the critical frequencies and one of the elements. This theorem is more fully explained and its use demonstrated in Section 3.4.

3.3 Method 3

Tuned transformers which have a symmetrical form, or which, by the introduction of an ideal transformer, Fig. 36, can be reduced to a symmetrical form, may be dealt with more simply than is possible with Method 2 by a process of circuit transformation into the symmetrical lattice form. An example of such a transformation is shown in moving from Fig. 34 to Fig. 38. The method then reduces to the general method of design described in Section 3.2, when Z_s and Z_L, the impedances respectively of the series and lattice arms of the lattice network are made to replace the open and short-circuit impedances Z_{oc} and Z_{sc}. The simplification to Method 2 arises because the number of circuit elements involved is reduced by about one half.

3.3.1 Use of Bartlett's Bisection Theorem

Bartlett's Bisection Theorem[1] is used to transform to the lattice network from the equivalent T- or π- of the tuned transformer. As an example of the use of this theorem consider Fig. 17. It is necessary when using Bartlett's Bisection Theorem in order to obtain the equivalent symmetrical lattice network, to introduce an imaginary vertical centre line such that the portion of the network to the left of this centre line is the mirror image of the portion to the right. This may be accomplished by modifying the positions and the values of certain elements, in the manner shown in Fig. 18, without altering the electrical form of the network. It will be seen that this resulting network is electrically identical with that shown in Fig. 17, and at the same time the above conditions are fulfilled. Bartlett's theorem, stated simply, says that the pairs of two-terminal networks forming the lattice and series arms of the equivalent lattice network are respectively identical with the two terminal networks presented between terminals *e* and *f*, Fig. 18, when all the connexions passing through the centre line *a b* are disconnected or all connected together. In this particular case the resulting lattice network shown in Fig. 19 is the balanced equivalent of the unbalanced network shown in Fig. 17. In a similar manner the equivalent symmetrical lattice network of any symmetrical ladder network may be obtained.

3.3.2 Examples of Lattice Transformation

By way of explanation consider the unbalanced symmetrical T-network shown in Fig. 20, and the equivalent balanced network shown in Fig. 21. The well-known equivalent lattice network[10] is shown in Fig. 22 and it will be seen that this network is identical with that obtained by the application of Bartlett's theorem to the ladder networks of Figs. 20 or 21. When impedances are added in series with the lattice network of Fig. 22, as shown in Fig. 23, the lattice portion of this network may be replaced by the equivalent balanced T-network of Fig. 21 and the resulting equivalent network of that shown in Fig. 23, is shown in Fig. 24. From the well known equivalence of the networks shown in Figs. 21 and 22 it will be seen that the lattice network shown in Fig. 25 is equivalent to the network in Fig. 24 and is thus also equivalent to the network in Fig. 23. In a similar manner, using balanced and unbalanced π-networks in place of the T-networks and employing the well-known equivalence[10] of the networks shown in Figs. 26, 27 and 28 it will be seen that the networks shown in Figs. 29, 30 and 31 are equivalent to each other. From the foregoing it will be seen that if identical impedances are connected in series or in shunt with each side of a lattice network, the equivalent lattice network comprises the original lattice structure, with the total impedance added to one side of the original network connected respectively in series or in shunt with each arm of the original lattice. This may be seen from an inspection of Figs. 23, 25, 29 and 31. By means of these useful equivalent networks, which are frequently used in the design of electric wave filters[8], the equivalent lattice network of complicated symmetrical ladder-networks may be obtained. The simple T- or π-section at the centre of the ladder-network is first transformed into an equivalent lattice structure and the remaining series and shunt elements are successively taken into the lattice-network. When bridging impedances are present in the ladder network, as the series and shunt elements are successively taken into the simple lattice network, at a certain stage the bridging impedances will be in parallel with the series arms of a lattice network and may be included as part of the series arms of that network. By way of a typical example consider the symmetrical ladder network shown in Fig. 17. This network is shown in balanced form in Fig. 32 and when the balanced T-portion at the centre of this network is replaced by its equivalent lattice structure, the complete network is as shown in Fig. 33. The bridging impedances, $Z_1/2$, may be incorporated in the series arms of the lattice network and when the shunt impedances, Z_2, are taken into the lattice structure, the network shown in Fig. 19 is obtained. This demonstrates the results to be obtained by the more direct method, using Bartlett's Bisection Theorem.

3.3.3 Example of use of Method 3

The design data for tuned transformers type 2.B will now be derived by means of Method 3. A transformer of this type is shown operating between two resistive loads R_1 and R_2 in

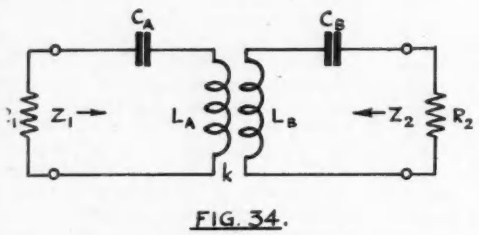


FIG. 34.

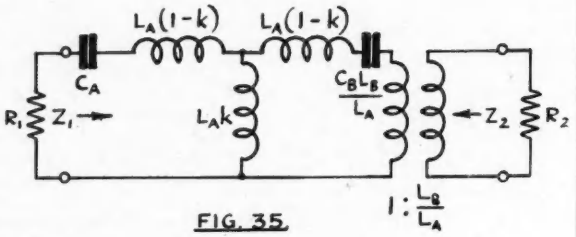


FIG. 35.

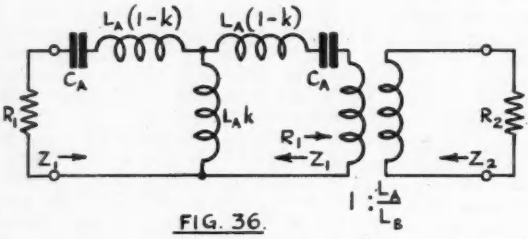


FIG. 36.

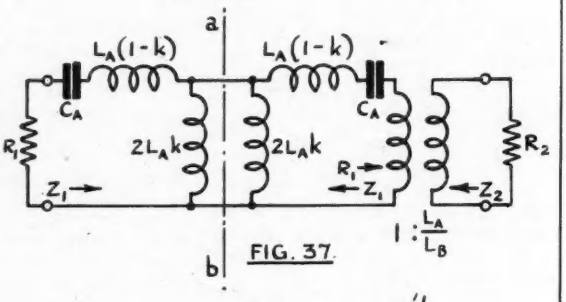


FIG. 37.

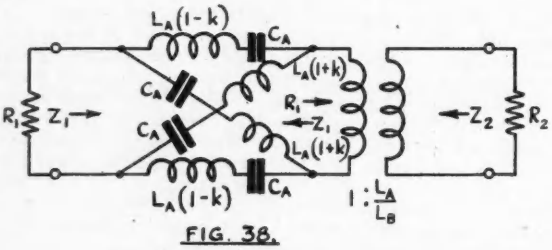


FIG. 38.

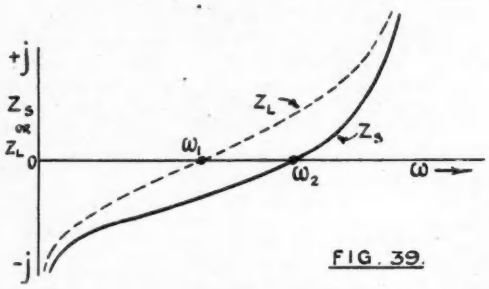


FIG. 39.

Fig. 34. An equivalent network of the type in Fig. 8 is shown in Fig. 35, and since it is necessary when using Method 3 that the network shall be symmetrical, the two capacitances and the two resistive loads must be made equal in value. The resulting symmetrical network is then as in Fig. 36 and as this network is equivalent to the networks shown in Figs. 34 and 35 it will be seen that :—

$$\frac{L_A}{L_B} = \frac{C_B}{C_A} \quad \ldots\ldots (28)$$

and

$$\frac{R_1}{R_2} = \frac{L_A}{L_B} \quad \ldots\ldots (29)$$

The network shown in Fig. 36 may, without alteration to its electrical characteristics, be realised in the form shown in Fig. 37 and applying Bartlett's Theorem the equivalent symmetrical lattice network, Fig. 38, is obtained.

The impedances of the series arms Z_s, and the lattice arms Z_L, are as follows :—

$$Z_s = j\left[\frac{\omega^2 L_A C_A(1-k) - 1}{\omega C_A}\right] \quad \ldots\ldots (30)$$

$$Z_L = j\left[\frac{\omega^2 L_A C_A(1+k) - 1}{\omega C_A}\right] \quad \ldots\ldots (31)$$

From an inspection of the impedance-frequency characteristics of the series and lattice arms, shown in Fig 39, it will be seen that a single pass band extends between the frequencies corresponding to ω_1 and ω_2, and hence these two frequencies are the cut-off frequencies.

Z_s is zero when ω is equal to ω_2 and from Equation (30) :—

$$\omega_2^2 L_A C_A(1-k) = 1 \quad \ldots\ldots (32)$$

Z_L is zero when ω is equal to ω_1 and from Equation (31) :—

$$\omega_1^2 L_A C_A(1+k) = 1 \quad \ldots\ldots (33)$$

The mid-band frequency is given by $\omega_m = \sqrt{\omega_1 \cdot \omega_2}$, therefore from Equations (32) and (33) :—

$$\omega_m^2 L_A C_A \sqrt{1-k^2} = 1 \quad \ldots\ldots (34)$$

The image impedance, Z_o, may be obtained from Equations (30) and (31) :—

$$Z_o = \sqrt{Z_s Z_L}$$

$$= j\sqrt{\frac{1 - 2\omega^2 L_A C_A + \omega^4 L_A^2 C_A^2(1-k^2)}{\omega C_A}} \quad \ldots\ldots (35)$$

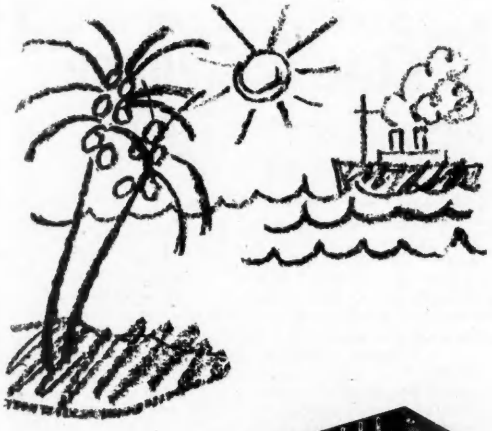
The image impedance, Z_m, at the mid-band frequency is made equal in value to the resistive load R_1.

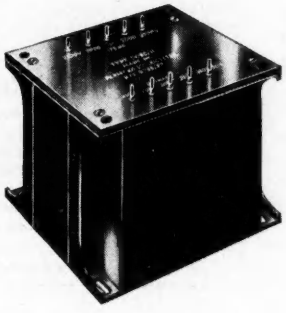
$\therefore$ from Equations (34) and (35) when $\omega = \omega_m$

$$Z_m = R_1 = \frac{1}{\omega_m C_A}\sqrt{\frac{2 - 2\sqrt{1-k^2}}{\sqrt{1-k^2}}} \quad \ldots\ldots (36)$$

Substituting for C_A in this Equation from (34) gives R_1 in terms of ω_m, L_A and k. This completes the necessary design data for tuned transformers of the type (2.B).

(To be continued.)





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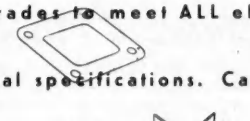

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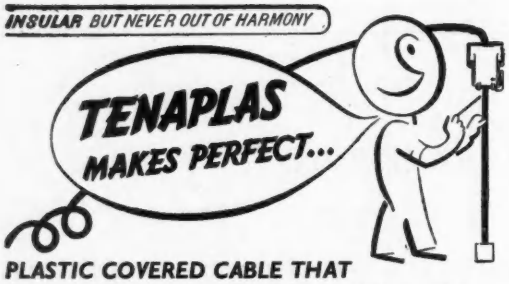

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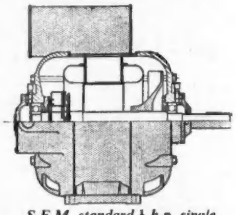

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The "Desynn" System of Remote Indication

By E. B. MOSS, B.Sc., F.Inst.P., A.F.R.Ae.S., M.I.A.E.*

This article is based on a Lecture given at an Exhibition of British Instruments for Science and Industry in Sweden in May, 1946.

THE "Desynn" system is an electrical apparatus enabling one to read on a dial, and at a distance, the setting of a control device or mechanism to which a transmitting element has been coupled. It is a self-synchronous system, and since it uses direct current the derivation of "Desynn" will be obvious. This equipment has been used almost exclusively on British aircraft since 1939, but although it was evolved for use on aircraft, it obviously has numerous industrial applications.

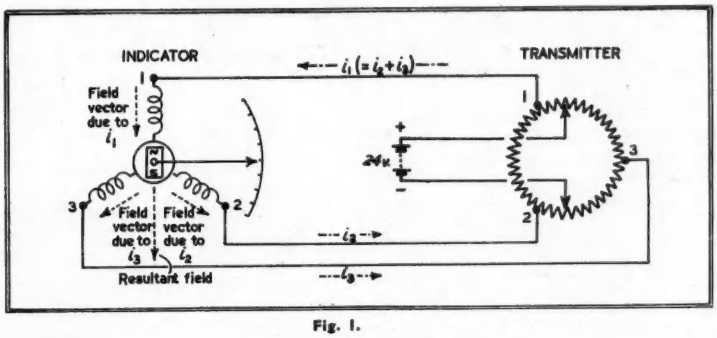

Fig. 1.

Theoretical Description

A set of equipment is made up of a transmitter and indicator connected together by 3-core cable, while the transmitter is also connected to the battery, as shown in the complete circuit diagram in Fig. 1. This indicates the most simple form of transmitter, embodying a toroidal resistance with three equally spaced tappings over which rotates a brush assembly making contact with diametrically opposite points and leading the current into the system.

The indicator has a 2-pole permanent magnet turning within a soft iron stator carrying a 3-phase distributed winding. This is connected to the tappings of the transmitter, and so the distribution of currents in the 3-phase winding depends on the position of the transmitter brushes. These circulating currents produce a magnetic field within the stator, which turns in synchronism with the transmitter brushes, and the magnet aligns itself with this field, carrying the pointer too. The direction of the magnetic field in the stator depends on the relative value of the currents, and not on the absolute value, so readings of the instrument are not subject to voltage variation. The current consumption of the equipment is about 30 mA on 24 V. Fig. 2 shows the construction of the simple transmitter. The rotating brush assembly carries an arm with a slot to receive the driving crank pin. This construction has appreciable friction, which does not matter in some applications, but another type of transmitter, known as the "micro" model, is designed for use where less power is available. This is operated by a short linear motion of only 2.5 mm. which produces the same effect as a 300° rotation of the brushes on

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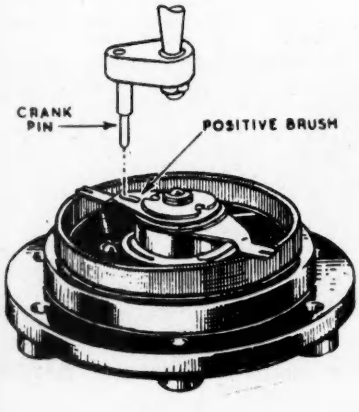


Fig. 2 (left). Construction of simple transmitter.

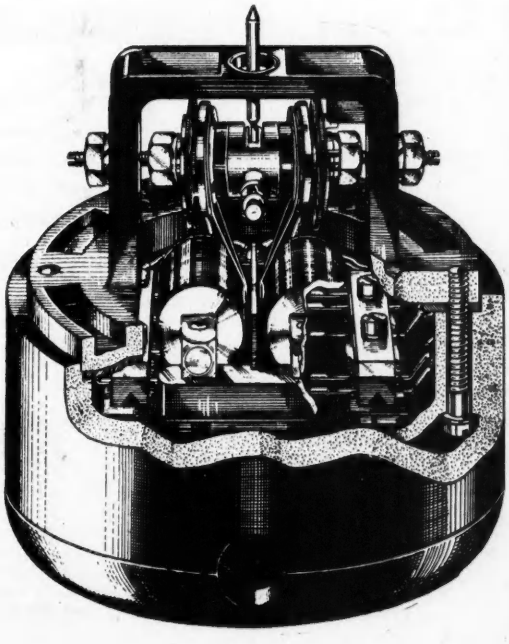


Fig. 4 (right). Cut-away drawing of micro-transmitter

a circular transmitter. In effect this device gives an electrical magnification for the brushes have only to rotate through 45° to slide over the length of two straight resistors each 25 mm. long.

The derivation of the circuit used in the micro transmitter from that in the circular type is shown in Fig. 3. The circuit shows that there are numerous tappings on the straight resistors and it would be difficult to solder all these in their correct positions, so pressure contacts are used, spaced at suitable intervals as shown with other features in Fig. 4. The current consumption of a set using the micro transmitter is 60 mA on 24 V. The push pin is spring loaded with a maximum force of 120 gr. and the friction losses are about 8 gr.

In both these transmitters the voltage of each of the tappings will vary proportionately with the rotation of the contacts, as shown in Fig. 5, and, unfortunately, the instantaneous sum of three such saw-tooth curves is not always zero, and one result is that the magnetic field in the indicator stator does not rotate in perfect synchronism with the transmitter contacts, being

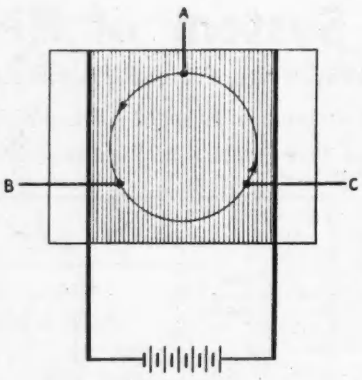


Fig. 6. Flat resistor element with contacts on rotating member.

subject to a slight cyclic error. This deviation is characteristic of the system, and being invariable can be taken into account in calibration. This applies also to the theoretical effect of the indicator load on the transmitter calibration. Nevertheless, it is an advantage if friction losses and cyclic errors can be reduced, and continuous development has resulted in the design of a third type of transmitter, with a resistor arranged as shown in Fig. 6. This resistance is wound on a flat former, and the supply connected to either end, producing a uniform potential gradient. The rotating member now carries three contacts, taking the place of the fixed tappings, and as these revolve their voltages vary according to a sine law, so that if the effect of the indicator load is omitted perfect synchronism is obtained. Another feature is that each contact is now called upon to carry less current, and this reduces wear. The physical form of such a transmitter is shown in Fig. 7.

The construction of an indicator movement can be understood by reference to Fig. 8, which gives a sectioned view of a double instrument for use on aircraft, measuring only 1¼ by 2½ in. It is built on a flanged brass tube with end cap containing the pivoted balanced rotor, and the stator fits on the outside. The stator is wound with very fine wire to ensure reasonable efficiency, so it would be difficult to load a stator of conventional design with the slots opening into the bore, consequently the slots open on to the

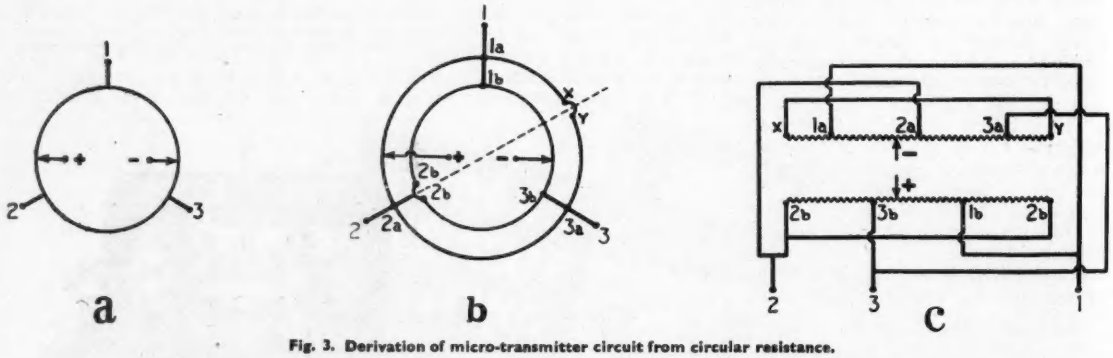


Fig. 3. Derivation of micro-transmitter circuit from circular resistance.

Fig. 5 (below). Voltage variation with rotation of contacts.

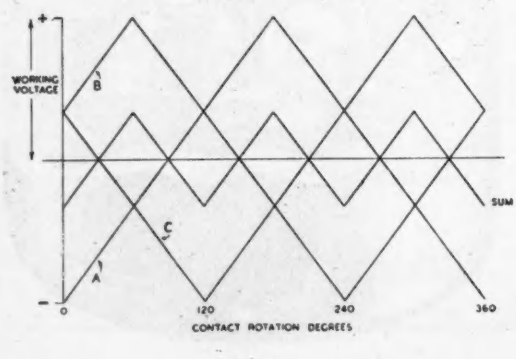
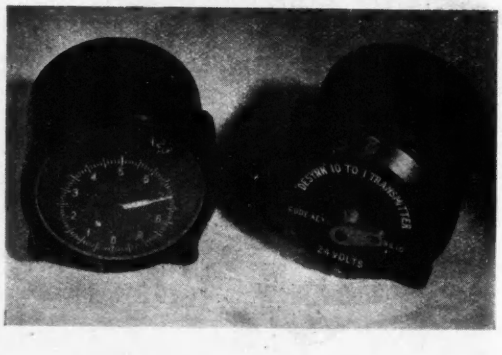


Fig. 10 (below). Transmitter with two elements geared in 10 : 1 ratio, and indicator.



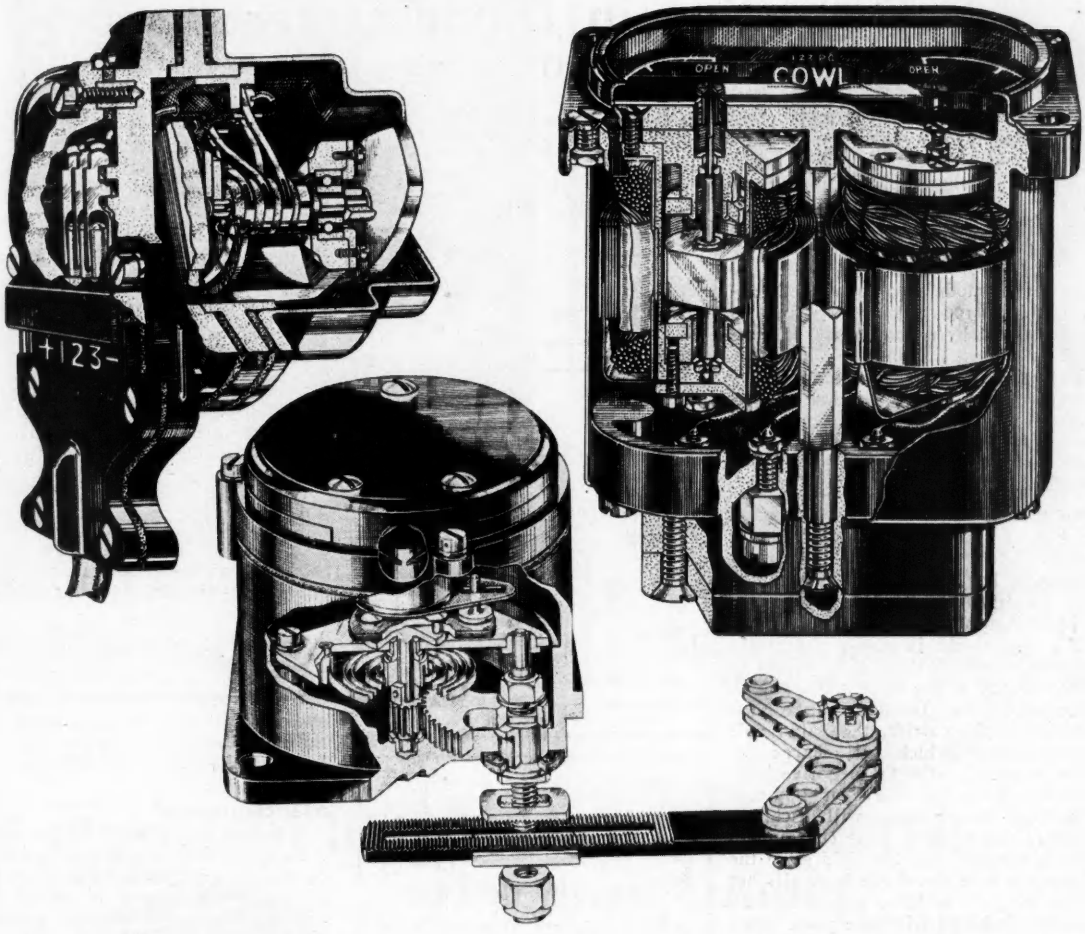


Fig. 7 (top left). Transmitter using flat resistance element of Fig. 6.

Fig. 9. Transmitter geared to adjustable arm.

Fig. 8 (top right). Cut-away drawing showing construction of indicator movement (double type).

outside and are closed finally by a ring of high permeability alloy. This instrument belongs to the moving iron class and is therefore liable to show effects of magnetic hysteresis. This would result in a difference between up and down readings, but actual hysteresis effects are reduced by the correct choice and treatment of the magnetic materials, so that the errors are usually less than 1°. When the rotor is displaced mechanically from a reading the forces acting on it are such that the torque required to move it 1° is approximately 0.08 gm/cm. This is a high figure and gives a torque/weight ratio of roughly 0.15, thus there is plenty of power to overcome friction in the substantial pivots giving a robustness not usually associated with electrical instruments. Also the forces acting on the rotor are such that the natural frequency is about 12 c.p.s. subsiding to a steady reading in about 0.4 seconds. A movement with increased damping can be made which gives a steady reading in 0.05 seconds. It is also possible to increase the torque to about 10 times the value mentioned above, although at some cost in accuracy, but the indicator movement can then be geared to the pointer mechanism and so the accuracy is recovered. It is sometimes necessary to have two indicators connected to one transmitter, this is possible with little sacrifice of accuracy and the indicators do not react on one another as in A.C. systems.

The indicators are made in two general forms for industrial work, one in a pressed brass case 4 in. in diameter, and the other in a 5 in. case when greater ease of reading is desired.

The form of transmitter is adapted to the application, but one in common use is illustrated in Fig. 9. The motion to be transmitted is applied to an arm of adjustable length, which has 60° of useful rotation, and internal gearing with a ratio of 3 or 6 : 1

(*Concluded on p.* 99)

Distortion in Diode Detectors

By R. A. LAMPITT, A.M. Brit.I.R.E.

IT is a generally accepted fact that when using a diode as a detector in a radio receiver, a certain amount of distortion is introduced merely by the use of an audio-frequency amplifier immediately following the detector. The distortion becomes more noticeable when the carrier is modulated to a depth approaching 100 per cent., and is accentuated by a bad choice of component values in the A.F. amplifier input circuit. Several efforts have been made to overcome this trouble, two of which are outlined below, but in order to appreciate them it is necessary to consider the cause of this distortion.

The Detector

Fig. 1 shows the principal circuit of a diode detector. The R.F. filter network has been omitted in order to simplify the diagram. When a signal is applied via the tuned circuit LC, the anode is made alternately positive and negative with respect to the cathode at the same frequency as the carrier E_s. On the positive half-cycles of the carrier, the valve will pass current which will charge the condenser C_L. On the negative half-cycles, when the valve is non-conducting, the condenser will discharge slowly through R_L. The charging of the condenser will be rapid since the impedance of the diode is small, but providing R is large compared with r_a the discharge will take place much more slowly. In consequence, a D.C. potential will be set up across R_L and this potential will be almost equal to the peak value of E_s minus the small peak voltage drop across the diode itself. In order to obtain a high degree of efficiency then, it is necessary to make R_L large compared with r_a and in practice a value of about 0.5 megohm is used. The efficiency is equal to 100 $R_L/(R + r_a)$ per cent. The time constant of C_L and R_L must be long from the point of view of the carrier frequency but short from an audio-frequency point of view, in order that the higher audio-frequencies may not be attenuated when the carrier becomes modulated. As a result of the modulation, therefore, there will appear across R_L an A.F. component in addition to the D.C. and very small R.F. components. It is the A.F. component which is passed to the next stage for amplification, before being applied to the output valve and thence to the speaker.

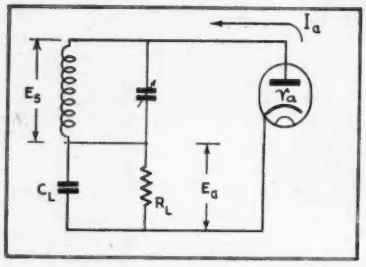


Fig. 1 (above)

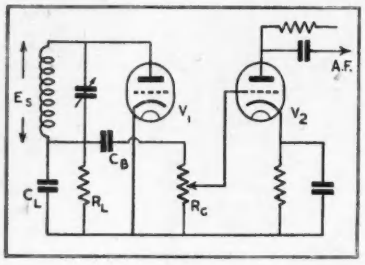


Fig. 2 (below)

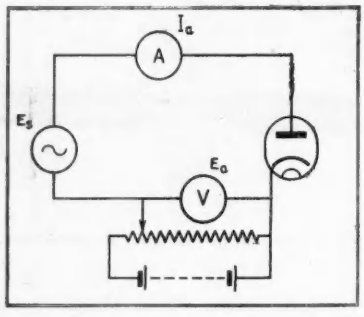


Fig. 3 (above)

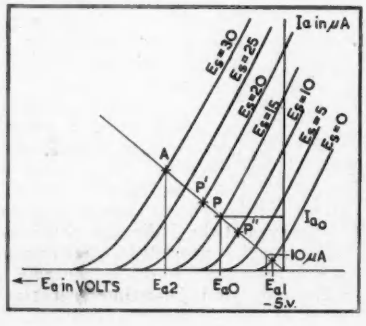


Fig. 4 (below)

Fig. 2 illustrates the usual method of coupling to the A.F. amplifier. As the triode must have a separate and constant bias, a direct coupling from R_L to the grid of V_2 cannot be made owing to the presence of the D.C. voltage component across the diode load. A blocking condenser C_B must be inserted, and a grid resistance R added in order to apply the correct bias to the grid of V_2. This resistance may be used as a volume control as shown.

If the carrier is unmodulated, the effective diode load is R_L, but under conditions of modulation when the reactance of C_B becomes small, R_G appears in parallel with R_L and the effective load becomes $\frac{R_L.R_G}{R_L + R_G}$. This different load on A.C. will cause the audio output applied to V_2 to be distorted above certain depths of modulation. This may be explained as follows:

Diode Characteristics

It is first necessary to draw a set of $I_a E_a$ characteristics and in order to do this it is advisable to simulate the normal working conditions of the valve. The circuit of Fig. 3 shows a variable negative bias being applied to the anode of the diode. This voltage takes the place of the D.C. component normally developed across the load and in practice it biases the anode back in proportion to the amplitude of the carrier. Figures are taken as indicated, and curves are plotted of I_a against E_a (E_a representing the "slide-back" voltage just mentioned) for different amplitudes of unmodulated carrier E_s. (Fig. 4.)

D.C. Load Line

It will be noticed that although E_s and E_a are both zero there is still a small current flowing through the valve. This is due to the thermo-couple effect produced between the anode and cathode of the valve. In Fig. 5 the artificial bias has been removed and a load resistance R_L and reservoir condenser C_L have been

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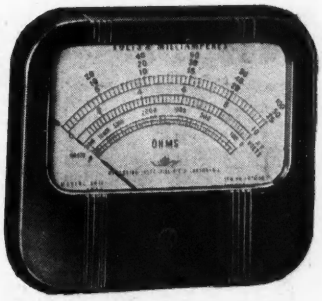

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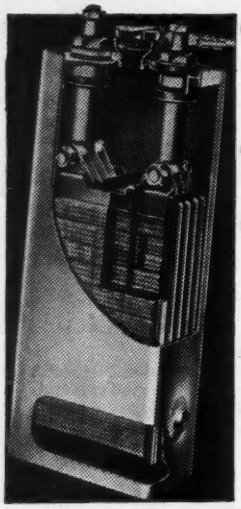

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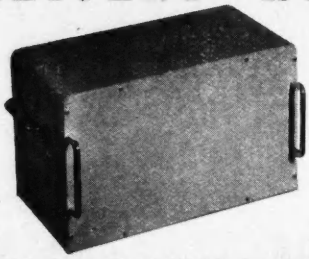

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substituted. Now, taking a load of 0.5 megohm, a current of 10 microamps will develop a P.D. of 5 volts and a point corresponding to this may be plotted on the graph. Also, when the anode current falls to zero, E_a will be zero, for it is the D.C. voltage component across R_L. Having plotted this point, a load line may be drawn through it, passing through the origin and extended to the left cutting the whole set of curves.

On receipt of an unmodulated signal, say, 15 volts r.m.s., a current I_{a0} will flow through the circuit, and a voltage E_{a0} will appear between the anode and cathode of the valve. This will automatically fix the operating point at P, which will lie at the intersection of the load line and the characteristic curve for $E_a = 15$ V. If the signal strength is increased to 20 V, then the operating point will move to P′, while if the signal is decreased to 10 V the point will move to P″.

When the 15-V carrier becomes modulated to a depth of 100 per cent. by an audio-frequency, the operating point will traverse the load line between points A and B in sympathy with the modulation of the signal. This will cause E_a to swing between E_{a1} and E_{a2} and an audio-voltage component will appear across R_L in addition to the D.C. component represented by E_{a0} (reproduced in Fig. 6).

If a 0.25 megohm load is used instead of 0.5 megohm, and a load line be drawn as before, the second load line will be much steeper and is indicated in Fig. 6 by the load line XO. The operating point will be P_1 for an unmodulated signal, and will move between X and Y when E_a becomes modulated to a depth of 100 per cent. It will also be noticed that the anode voltage swing is less than before, which indicates a drop in detector efficiency.

A.C. Load Line

In the case of a diode detector being followed by an audio-frequency amplifier, as in Fig. 7, the effective diode load is not R_L but $R_L.R_G/(R_L + R_G)$. This value is found by assuming the reactance of C_B to be small in comparison with R_G. This being so, C_B may be neglected and in consequence, R_L and R_G appear in parallel. The D.C. load remains equal to R_L, therefore the operating point will be on the D.C. load line whose slope is $-1/R_L$.

Taking a case where R_L and R_G are, say, each equal to 0.5 megohm,

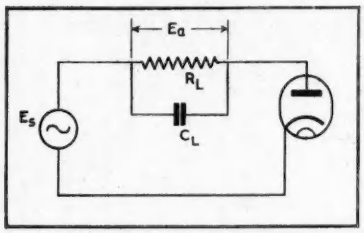

Fig. 5 (above)

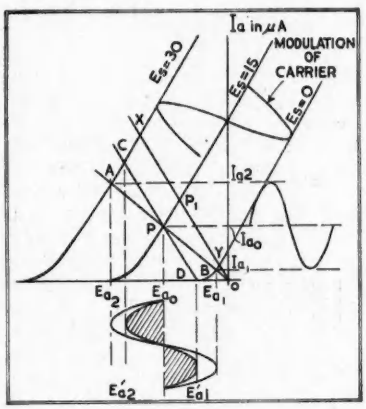

Fig. 6 (below)

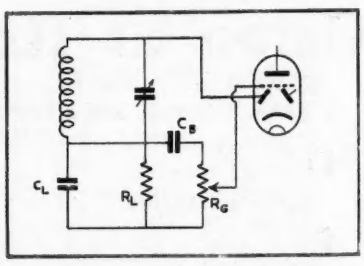

Fig. 7 (above)

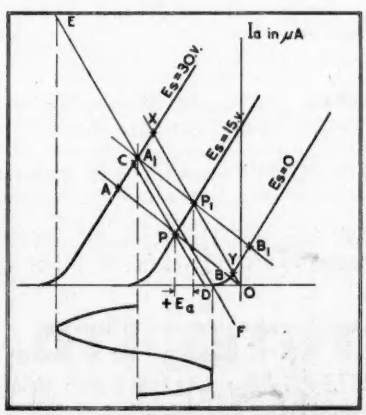

Fig 8 (below)

the static operating point will be P′, on the load line AO in Fig. 6. From an A.C. point of view, however, the load becomes equal to 0.25 megohm, so that the "dynamic" load line will have a slope of $-(R_L + R_G)/R_L.R_G$ which will be numerically equal to $-1/(0.25 \times 10^6)$ and will pass through the point P. This line is shown as CD.

Now assuming that the $E_a = 15$ V carrier is modulated to a depth of 100 per cent., the operating point will swing between C and D, thus taking the valve beyond cut-off and consequently introducing distortion. This is seen in the shaded portion of Fig. 6. If the percentage modulation is reduced sufficiently to prevent the valve from being cut off there will, of course, be no distortion. During a transmission, however, the modulation often reaches 100 per cent., so that normally distortion might be expected during loud passages. It is interesting to note that the maximum permissible modulation for distortionless reception can be calculated from the graph (Fig. 6) and is numerically equal to $100(E_{a0} - E'_{a1})/(E'_{a2} - E_{a0})$ per cent. It should be noted that the value of R_G in the above example has been chosen in order to enable the point to be illustrated more clearly, but it is not a practical value.

Remedies

The obvious way of reducing such distortion in practice is to ensure that the value of the diode load to A.C. is as near to the D.C. load value as possible and R_G should therefore be made as large as is practicable having regard to the maximum permissible grid resistance for the A.F. amplifier valve. This in practice is about 2 megohms, but unfortunately a volume control with a resistance of this value produces an appreciable attenuation of the higher audio-frequencies when set to give a reasonable volume of sound from the speaker. This is due to the fact that normally the slider of the control is set near the bottom or "earthy" end of the track, and in consequence the portion of its total resistance which appears in series with the signal and the grid is large. This is equivalent to a high value of grid stopper, and if the grid-cathode capacity of the valve is large, high-note attenuation is appreciable.

In view of this it is much more advantageous to make R_L the volume control and let R_G have a fixed value. This arrangement results in R_G having less effect on the diode load

since the ratio of R_d to the bottom part of R_L is large. Diode distortion in this case would be varied by the setting of the volume control but would only reach that obtained by the former method when the control was set to maximum, which, of course, would only be on rare occasions.

An effort has been made to remove the distortion by applying a small positive bias to the anode, and the effect of this is shown in Fig. 8. A positive voltage equal to $+E_a$ is applied, and in consequence, the D.C. load line will be moved to the right and will take up a position A_1B_1; the new operating point will be P_1, and the carrier will be 15 V as before.

Upon receipt of a 100 per cent. modulated carrier of 15 V, the A.C. load line will appear as XY, and as is seen, the distortion will be eliminated. It is obvious that this positive bias $+E_a$ will only give this particular result when the carrier has an amplitude of 15 V. For smaller values of carrier amplitude the distortion will still be zero but greater amplitudes may again produce distorted outputs. Assume the carrier to increase to 30 V amplitude. With the same value of bias $+E_a$, the operating point will move to A_1. When this carrier becomes modulated to 100 per cent., the A.C. load line will swing about this point and will take up a position represented by the line EF. The operating point will traverse this line between E and cut-off, and as a result the audio component in the output will become distorted. In spite of this there is a definite improvement since larger carrier amplitudes may be handled before distortion sets in.

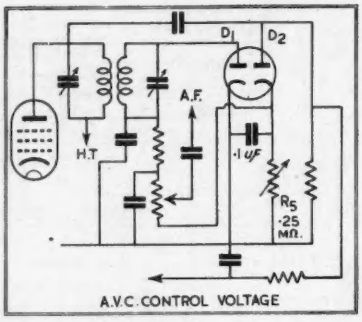

Fig. 9

The Self-Adjusting Circuit*

It is evident that the greater the carrier amplitude, the greater must be the positive bias in order to reduce the distortion still further. In view of this fact, a circuit has been developed which is self-adjusting (Fig. 9). The rectified current of D_2 develops a potential difference across its cathode load, and since the cathode then becomes positive with respect to earth, the anode of D_1 will be biased positively with respect to earth, the value of this bias being proportional to the carrier amplitude. The compensation obtained may be adjusted by making R_5 variable. A disadvantage of the fixed positive bias method is that it increases the damping on the tuned circuit at low carrier amplitudes. This is minimised by means of the self-adjusting circuit, since the positive bias at these low input levels is very small.

* *Radiotronics*, No. 74, March 31, 1937.

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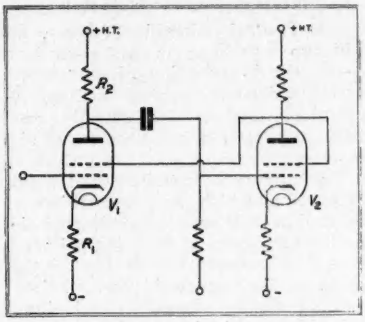
Cathode-Follower Circuit Using Screen-Grid Valves

IT is known that in a repeater stage of cathode-follower type the fraction of signal transfer from control-grid to cathode, may, if a triode valve is used, be caused to approach closely to unity. If, however, instead of a triode a valve having a screening grid is used, and the screening grid according to common practice is operated at a fixed potential, the transfer from control grid to cathode is not so great. This arises since the screen current necessarily passes through the cathode-load resistance and constitutes an anti-phase component of cathode current. Thus, if a change of potential of the control grid causes a certain increase of potential at the cathode, it is clear that the screen component of current in the cathode circuit is reduced, so that the rise of cathode potential cannot be so great as it would have been had the screen component not changed. In this article there is described a circuit arrangement that uses a screen-grid valve in the manner of a cathode-follower repeater but in which loss of signal transfer does not occur or is reduced.

The principle employed in this arrangement is one of applying signal variations to the screening grid. By doing this it will be evident that the screen potential may be so varied as to maintain the screen current constant and in consequence remove the transfer loss. As indicated in the circuit diagram a small load resistance R_2 is included in the anode circuit of the screen-grid valve V_1 acting as a cathode-follower and the resulting changes of anode potential of the valve V_1 are communicated to the control grid of an additional valve V_2. The anode circuit of the latter valve also includes a load resistance, and its anode is connected directly to the screen grid of the first valve. The second valve may have a cathode-biasing resistance to improve its linearity of operation.

With the arrangement illustrated, assuming that the magnitude of the cathode-circuit resistance of the cathode-follower valve V_1 is R_1 and that the gain of the associated valve V_2 is A, it may be shown that there is no loss of transfer between grid and cathode of the valve V_1 due to the



presence of its screening grid when

$$R_2 = \frac{1}{A}\,\frac{I_K}{I_A}(R_1 + \rho),$$

the ratio

$$I_K/I_A$$

being the ratio of cathode to anode current of the valve V_1 in operating conditions. ρ is the differential anode impedance of the valve V_1.

By suitable choice of circuit parameters the transfer loss of the stage may be compensated not merely so that the stage simulates a triode stage but so that compensation takes place in any desired degree. If desired, by over-compensation the transfer fraction may be made greater than that of the equivalent triode stage and may even be made equal to unity. It is important to bear in mind, however, that the control exercised on the screen grid introduces positive feedback into the circuit, and, therefore, in some circumstances the circuit will tend to oscillate.

When, for instance,

$$R_2 = \frac{1}{A}\,\frac{I_K}{I_A}(R_1 + \rho),$$

so that exact compensation is achieved, the impedance looking into the cathode of the valve V_1 has the value

$$\frac{-R_1}{\mu + 1},$$

where μ is the magnification factor of the valve V_1 The impedance it will be seen is negative so that the stage is liable to oscillate.

The impedance is zero when the circuit is under-compensated to the degree given by

$$R_2 = \frac{1}{A}\,\frac{I_K}{I_A}.\rho.$$

The circuit possesses a certain property of interest in respect to input impedance. In certain circumstances it may be caused to present a negative component of input capacity which may conveniently be used to neutralise undesired or stray capacity associated with the input circuit. The property depends on the existence of the capacity between the screening grid and the control grid. In the absence of any signal variations applied to the screen grid this capacity would be present in the input capacity of the valve. If, however, just such signals are applied to the screen grid as are applied to the control grid the capacity is effectively removed. If greater variations are set up on the screen than on the control grid a negative capacity may be established in the input circuit. The ability to cancel capacity in the input circuit is important in the repeating of pulse signals where a rapid rise with the incidence of the leading edge of the pulse is required.

—Communication from E.M.I. Laboratories.

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WORK in progress on the impedance bridge technique, originated by Mr. C. G. Mayo and the B.B.C. Research Department and now under intensive development by this Company, indicates that by this method measurement of balanced and unbalanced impedances can be made with useful accuracy beyond 200 Mc/s.

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NOTES FROM THE INDUSTRY

Electron Jubilee Celebrations

The fiftieth anniversary of the discovery of the electron by Sir Joseph Thomson, O.M., will occur next year, and to mark the occasion the Institute of Physics and the Physical Society are jointly arranging a series of meetings and other functions to take place on September 25 and 26, 1947, in London. A special exhibition which will remain open to the public for several weeks, will be held at the Science Museum, South Kensington, and will show the development of the vast range of modern industrial equipment from its earliest experimental origins.

Radiolympia 1947

The Radio Industry Council announces that the National Radio Exhibition will be resumed in 1947. Present plans envisage a pre-view on September 30, and the show to be open to the public from October 1 to 11. This will be the first opportunity since before the war for the British radio industry to display to the public its outstanding achievements in the design and production of radio, television, radar and electronic apparatus for civilian purposes.

H.F. Heating Brochure

An outline of the progress which has been made in high frequency heating is given in a brochure—" High Frequency Heating by Valve Generators "—just published by The General Electric Company, Ltd.

The brochure, a copy of which can be obtained on application to Magnet House, Kingsway, W.C.2, is well illustrated throughout its 28 pages. Complete sections are devoted to the heat treatment of metals, *i.e.*, eddy current heating, and to heat treatment of non-metals, *i.e.*, dielectric heating. Details are given of the range of G.E.C. generators, comprising 100 watt, 1 kW, 5 kW and 25 kW models and prospective users are given a fair estimate of what can be expected of each.

Philco Car Receiver

Philco announce a new car radio for 1947. Housed in one unit, but having a separate tuning control, it weighs less than 12 lb. and suppressor equipment is a matter of personal choice. The set will be priced at £21 plus £4 18s. 3d. purchase tax.

Mercury Vapour Detector

The Central Scientific Company of Chicago announce in an advertisement* the introduction of a mercury vapour detector which utilises a chemical method for detecting as little as 7 parts per 100,000,000 of air in an hour.

The apparatus consists of a truncated cone which acts as a chimney through which a constant flow of air is provided by a 25-watt lamp in the base. Fastened to the top of the chimney is a curved paper holder accommodating strips of selenium-sulphide-sensitised paper $\frac{7}{8}$ in. by 2 in.

A calibrated colour chart with a scale of six shades of grey for matching the test paper and a scale indicating concentration of Hg vapour is provided. An exposure of an hour is recommended for a detection of 7 parts per 100,000,000 air, but for the toxic limit (1.3 parts per 100,000,000) an exposure of six hours is required.

The price is $50.00 in U.S.A.

**Science*, Feb. 15, 1946.

New Research Laboratories

Elliott Brothers (London) Ltd., are setting up new research laboratories at Elstree Way, Boreham Wood, Herts. Mr. J. F. Coales, O.B.E., M.A., late of the Admiralty Signal Establishment, will be in charge, and the new organisation will undertake the development of all types of industrial and laboratory instruments and specialised equipment. It is also proposed to develop new techniques for the control of manufacturing processes.

Literature Received

The Reid and Silgrist Electronic Balancer.

T.C.C. Electrolytic Capacitors " Glasgow-Rex " H.R.C. Switches and Fuse-Switches. (Midland Electric Manufacturing Co., Ltd.)

Eddystone Short - Wave Components. (Stratton and Co., Ltd.)

Somerford Smoothing Chokes. (Gardners Radio Ltd.)

All-wave Signal Generator, type 505. (Sphere Radio Ltd.)

DS10 Transmitter (Standard Telephones and Cables Ltd.)

Mazda Radio Valves and Cathode-ray Tubes. (Edison Swan Electric Co., Ltd.)

Panalysor. A Radio Heterodyne Spectroscope. (Panoramic Radio Corporation, America).

Philips Battery Chargers. (Philips Lamps Ltd.).

The A.B.C. of High-Frequency Heating of Metals. (Philips Lamps Ltd.)

Two New Laboratory Instruments

Two new laboratory instruments are now available from Dawe Instruments, Ltd. Type 230a Decade Inductometer is a four-dial decade box having a total inductance of 111.1 millihenries in steps of 10 microhenries. This inductor is suitable for use as a standard of moderate accuracy for measurement of self inductance, and as the component of bridges, oscillators and similar equipment where a variable inductor is needed as a circuit element. It can also be used with the Impedance Comparator type 303A for the routine testing of coils within specified inductance values. The price of the instrument is £35.

The other instrument is a Ratio Arm Box type 300A, suitable as a basic element around which to assemble any bridge circuit, and priced at £13 10s.

New Instructional Film by Ediswan

The increasing use of electronics in industry has created a demand for a simple explanation of the principles of this new branch of electrical science which should appeal to the student as well as to those who have been unable to keep in touch with recent theory.

The instructional film, " They're Called Electrons " has been made for The Edison Swan Electric Co., Ltd., by Wallace Productions Limited in collaboration with Studio Film Laboratories and Mr. G. Parr, Editor of *Electronic Engineering*. It is an ideal medium for expounding the elementary electronic theory in a graphic form which can be appreciated by all. Clever photography and cartoon work help to establish an understanding of the infinitely small by studying the release of the elementary electron from the atom. Its action in the thermionic valve used for transmitting and receiving radio signals is then demonstrated. It is intended that this film, and others to follow, shall be available to schools and training centres which have access to 35 mm. and 16 mm. sound projectors. It is three reels in length and runs just under half an hour.

British Rola Ltd.

The London Sales Office of *British Rola Limited* is now at 8 Upper Grosvenor Street, W.1. (Telephone: Regent 7566.)

Simmonds Aerocessories, Ltd.

It has been decided to close the Great West Road works of the Head Office organisation and Research Departments of the company to their Treforest works, nr. Pontypridd, Glamorgan, South Wales. The London office at 2/3 Norfolk Street, Strand, and the Regional offices are unaffected by this change.

Mr. W. H. Stevens

Mr. W. H. Stevens, until recently in charge of television development at R.F. Equipment, Limited, makers of "Sobell" radio receivers, has been appointed chief engineer of the company.

Dr. R. C. G. Williams, B.Sc.

It is announced that Dr. Williams, at one time with Murphy Radio, Limited, has joined the North American Philips Company Inc., of New York, as an executive engineer.

Bitone Reproducers

Vitavox Limited are introducing a new reproducer specially designed to facilitate high quality sound reproduction in small halls, cinemas and similar auditoria. The reproducer has a multi-cellular horn consisting of a number of small horns, correctly orientated to give adequate coverage, and a moving coil pressure unit with a light-weight diaphragm specially designed for high-frequency reproduction. Full details of this unit can be obtained from Vitavox, Limited, Westmoreland Road, London, N.W.9.

Electronically Controlled Model Train

Electronic engineers who are also model railway enthusiasts will be interested to learn that a train with full electronic control by means of radio signals is now available in the United States. The outfit comprises a n"o" gauge, 6-8-6 steam locomotive, tender, four cars of different types, track, control equipment, etc., and has the following features: "Start," "stop" and "reverse train" electronically, whistle blown electronically, cars uncoupled electronically, and even unloaded electronically. All of which can take place anywhere on the track. Each unit of the train contains a miniature radio receiver and the control desk is, of course, a small transmitter.

Further details of the equipment can be obtained from the Lionel Corporation, 15th East 26th Street, New York 10, N.Y., U.S.A.

Electrical Engineering Book List

The National Book League has just issued a Book List on Electrical Engineering in its well-known series of Book Lists, of which over 200 have now been published. This Book List was compiled by the late J. Corthesy, librarian of the Institution of Electrical Engineers.

The price of the Book List is 8d., including postage. Copies are supplied free of charge to all members of the National Book League. The League now has more than 10,000 members, including many industrial firms, which find its literary information services of great value. The annual subscription for individual members is half a guinea; for a commercial firm or industrial firm it is two guineas. Full information can be obtained from the General Secretary at 7 Albemarle Street, London, W.1.

The "Desynn" System

(*Concluded from p.* 93)

is used to drive the transmitter itself. Another type has a ¼ in. spindle projecting from a flanged case and this spindle is capable of unlimited rotation, the pointer of the indicator connected to it rotating in synchronism.

Generally, the accuracy which can be obtained with these components is about 3° on the indicator scale. If still greater precision is needed then this can be achieved by gearing up the transmitter so that the indicator pointer makes many rotations. This introduces the possibility that the indicator may get out of step with its transmitter, consequently it is usual in this arrangement to add an additional set to count the turns, or, in other words, "coarse" and "fine" transmitter channels are employed. Fig. 10 shows apparatus of this type, the transmitter unit housing two elements, one connected directly to the operating shaft, the other revolving at ten times the speed, thus it makes one turn for 36°, as shown by the main indicator dial, the revolutions being counted by a dial on a second indicator mechanism seen through a window at the top.

Obviously, the industrial applications of this device are almost unlimited, one general use is to show the contents of storage tanks for fuel and other liquids, another is to give remote indication of the setting of transformer tapping switches. Other applications will be obvious to technicians dealing with other fields.

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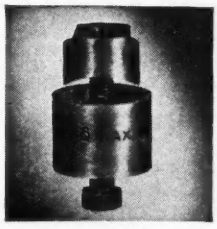
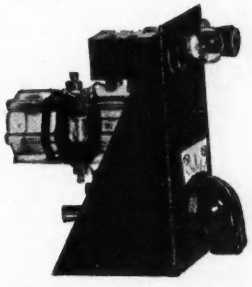


THE "Q-MAX" CHASSIS CUTTER

Does away with tiresome drilling and scraping. Holes cut easily and cleanly. Punch cuts through chassis, die prevents distortion, spanner turns bolt to cut holes.

Size of holes 1⅛ in. (octal) 10/6
" " 1⅛ in. and 1½ in. 12/6
(Post 9d. extra)

(Patent Applied for)



THE "Q-MAX" ABSORPTION WAVEMETER AND PHONE MONITOR

An Absorption Wavemeter for checking frequency harmonics and parasitics in Oscillators, Doublers and Power Amplifiers.
All amateur bands covered by plug-in inductances. Incorporated in the Wavemeter is a WX6 Westector—automatically connected across the tuned circuit by inserting phone jack plug for monitoring phone transmissions. Size 3¾ in. by 2 in. by 2 in. Price ... 35/-
(Price includes one inductance. Extra inductances 3/9 each.)

Obtainable from your local Q-Max dealer or direct from:

BERRY'S (SHORTWAVE), LTD.
25, HIGH HOLBORN, LONDON, W.C.1
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BOOK REVIEWS

Two Electronic Handbooks

Electronic Engineering Handbook

by R. R. Batcher & W. Moulic and others, (456 pp. 460 figs. and tables plus appendix data, 1944. Approx. price in Britain, 22/6d.)

Electronic Control Handbook

by R. R. Batcher & W. Moulic, (334 pp. 296 figs. and tables, 1946. Price, $1.00 plus two years' subscription ($8) to "Electronic Industries" (U.S.A.). Both published by Caldwell-Clements, Inc., 480, Lexington Avenue, New York 17, N.Y., U.S.A.)

These two handbooks, apparently the first of a series to be issued by the American journal *Electronic Industries*, strike a new note in the literature of applied electronics and fully justify their claim to be working references for "specialists in electron tube applications, plant managers, production heads" etc. Most texts so far available fall into two classes, namely theoretical treatises useful to students but of limited value to designers, or purely practical works describing a few applications in detail but giving little assistance in solving new problems. Messrs. Batcher and Moulic however, who are connected as editors with *Electronic Industries*, have successfully bridged the gap in providing two really useful reference books which should be widely used. They possess the rare and happy knack of presenting technical information in an easily assimilable manner, and both books are notable for clear readable style which is neither dry nor on the other hand descends to the irritating and condescending use of colourful adjectives and idioms which have spattered many semi-technical publications (especially American) of late. Whereas many texts give the impression of being stereotyped digests of earlier books, the authors are original in outlook and have always something interesting to say. No space is wasted on basic electric circuit principles, but every chapter builds up in an obviously knowledgeable, up-to-date manner. Circuit diagrams (many with values), line drawings, tables, charts and nomograms are liberally used and styled for ready digestion. Unusual emphasis is given to design features, linked with theoretical and practical data which, as well as drawing pointed comparisons between different circuits and techniques, is presented in forms easy to use and saving much laborious calculation. In this respect the authors have taken full advantage of manufacturers' co-operation in assembling together much practical and widely-scattered data on tubes, auxiliary components and circuits.

The first book deals mainly with fundamentals. Section I on "Vacuum Tube Fundamentals," covers tubes of all kinds: thermionic, photo-electric, cathode-ray (including the Skiatron and camera tubes), gas, vapour and pool types (including cold-cathode triode, permatron, ignitron, etc.), velocity-modulated and magnetron tubes. Construction and equivalent circuits are shortly discussed. "Electronic Circuit Fundamentals" then deals with rectification (including stabilising, multi-anode and heavy-duty working); amplification (including dynamic characteristics, much detail on LF and HF design, inverse feedback, neutralising (long discussion) and UHF limitations; oscillators (including UHF types and resonance transformers for obtaining HV power supplies); modulation (covering AM, FM and PM); detection; CRO's (all parts of the system with complete Dumont circuits and an electronic switch); relaxation oscillators; photo-electric circuits (with a useful collection of commercial arrangements); electron tube circuit applications (emphasis on discriminating possibilities such as clipping and frequency variations, an especially interesting discussion on replacing conventional load resistors by tubes in amplifiers, forming "series-tubes" connexion, and notes on minute current amplifiers and the cathode follower). Section III, "Electronic Applications," contains details on two topics which the editors consider worthy of special attention, namely high frequency heating and industrial sound systems. Contributed by specialists, the first is an excellent review of both induction and dieleetric heating, in fact the best yet published, including not only application technique but power supplies and costs, several nomograms and data tables on both conductors and dielectric materials. The second chapter is concerned with the acoustical and electrical problems of both indoor and outdoor sound systems of many kinds, and deals very capably with components, circuits and typical installations. The final section, in the nature of an appendix, comprises 28 pages of data on vacuum and gas rectifiers, triodes tetrodes and pentodes for industrial, transmitting or special uses, phototubes, thyratrons and ignitrons (sub-divided into welder and rectifier types). The only references in this volume are a few which appear in the chapter on HF Heating.

Books reviewed in this Journal can be obtained from

H. K. LEWIS & Co. Ltd.

136 Gower Street, W.C.1

If not in stock, they will be obtained from the Publishers when available

"Electronic Control Handbook" is remarkable as the first book, it is believed, to present a general treatment of transducers (or energy converters) from the viewpoint of the electronic engineer. As the title implies, this work is devoted to the practice of automatic control systems, which include many mechanical as well as electrical problems. Basic elements of control are first discussed, a particular difficulty being time lags of various kinds which cause hunting and errors. Controller types and electronic control methods by amplitude, frequency, phase shift, pulse and polarity are generally covered. In Section II, on "Conversion Elements," there is collected together in about 90 pages the most comprehensive practical data on transducers which this reviewer has ever seen, and which will make the book invaluable to workers in many branches of technology. Displacement and pressure converters include optical, contact, capacitor, inductor, resistor and piezo-electric types, with special emphasis on topics such as velocity and displacement, magnetostriction, pressure conversion, strain gauges, tuned wires and the electret. Temperature conversion elements for high and low temperatures include pyrometers of the brightness (photo-electric) type, thermo-resistance (useful data on thermistors to be especially noted), radiometers, thermocouples, bimetallic expansion, bolometers, thermosensitive magnetic alloys, pyro-electricity and dielectric constant conversion. Miscellaneous topics cover viscosity, dielectric constant applications generally, pH control of acidity and alkalinity, humidity and moisture content by several methods, flow measurement, response to "rays" and colour. Section III deals with "Electronic Modification Circuits" useful in control. Amplifiers are generally reviewed, with special attention to feedback, matching, inverting, etc., and particular examples are given for impulse counting, high current, strain gauge, motor control, low current and phototubes. Further topics are oscillators, counting and timing controls, rectifiers for de-modulation, and special passive networks such as unbalanced bridge circuits and special bridge applications, RC filters, transient response and integrating circuits. Finally in this section, deviation detection of voltage and frequency changes is dealt with. Activation elements or output devices are described in Section IV, which contains much interesting material on synchros and servo systems, solenoids and relays (including electronic types), saturable reactors and motors for control purposes. The final Section V, very strangely titled "Control Motors," is actually devoted to various specific industrial electronic applications. Welding control is followed by a chapter on speed control, which in addition to electronic methods discusses the amplidyne. The last chapter details a number of miscellaneous applications which illustrate

various subjects raised in earlier chapters. The book is completed by a 3-page selected bibliography which, together with the ample lists at the ends of many of the chapters, forms a most useful set of references.

Altogether, these two books are to be highly commended. The first is valuable, the second indispensable to those dealing with a wide range of electronic problems. The sales feature of issuing the "Control" book only with a subscription may be annoying to many, but at the very nominal price the combined book and journal are an excellent bargain.

J. C. FINLAY

Introduction to Electron Optics

The Production Propagation and Focusing of Electron Beams. By V. E. Cosslett, (Oxford University Press, 1946.)

This is the first book on electron optics in the English language written by an experienced teacher. While the other excellent textbooks intend chiefly to provide the electronic engineer or the research worker with material and methods, this is a didactical book, and it fulfils its purpose admirably. The treatment is throughout elementary—surprisingly so for a book in the International Series of Monographs on Physics—and it can be fully understood by anyone with a knowledge of elementary calculus and without any previous acquaintance with electronics. But as an inevitable consequence of the restrictions which the author has imposed on himself, the 272 pages of the book are sufficient only for a bare introduction of the vast subject.

The first 172 pages of the book are devoted to an elementary explanation of the production of free electrons, and their dynamics in deflecting and focusing fields. Graphical, numerical, model and experimental methods of field determination and ray tracing are strongly emphasised at the expense of analytical methods. It is gratifying to find lucid descriptions of the new methods worked out by Motz and Klanfer, and by Klemperer and Wright, which appear for the first time in a textbook. On the other hand it appears that somewhat more consideration could have been given to problems of intensity than the few remarks on p. 156. Almost all the rest is devoted to fields and the geometry of trajectories. A discussion of the effects of space charge in electron beams has been omitted altogether.

The next 76 pages contain the discussion of electron optical devices, ranging over the whole field of cathode ray tubes, electron microscopes, diffraction cameras, velocity and mass spectrographs, particle accelerators and electron valves of all types. Even more than in the first part, the space is sufficient only for a first introduction, but it is supported by carefully selected lists for further reading.

The volume is closed by a discussion of the Hamiltonian Method on 14 pages, which is exemplary in its conciseness and clarity. It will enable the student to study almost all advanced original papers. Perhaps it might be desirable to add to later editions similarly clear and concise notes on wave mechanics and on relativity dynamics.

There are few mistakes in this carefully written book. In Fig. 22, and in the explanatory text on p. 33 the kinematics of the three-wheel trolley is wrong. All wheels ought to be at right angles to the radii drawn from the instantaneous centre. On p. 43 "symmetrical" and "univoltage" lenses are used as synonima, though this is corrected later on pp. 62-68. But the name "symmetrical" lenses is not very happily chosen for what usually goes by the name of "single" lenses. A good opportunity has been missed here to clear up the regrettably confused terminology of the subject. On p. 123, (last lines) the reader is left with the impression that it might not be impossible to compensate the spherical aberrations in electron lenses, though three pages later Scherzer's result is quoted, which categorically denies this possibility. On p. 135 the impression is given as if the Petzval condition would remove astigmatism and image curvature simultaneously, whereas it would be more correct to say that it flattens out the field if the astigmatism is compensated. On p. 205, after consulting Fig. 122 and the explanatory text the reader is still left wondering how anything is made visible in the electron microscope, as nothing is said about the origin of contrast.

The book is well illustrated, clearly readable, and is likely to become very popular with young physicists and electronic engineers.

D. GABOR

Electrical Contacts

L. B. Hunt *et al* (Johnson, Matthey & Co., 10/6d. net).

"The purpose of this book is to place at the disposal of the electrical engineer information which will enable him to make a wise selection of material and form of contact for the majority of applications."

No one will question the authority of Messrs. Johnson and Matthey to publish a work on contact materials, and Dr. Hunt and his colleagues have set down the results of many years specialised study of precious metals and their properties in circuits.

There are examples of the design of light and heavy contacts, with tables of recommended metals and numerous examples taken from industrial apparatus. A separate chapter on the properties of contact materials summarises all the special alloys and metals with notes on their particular application and technique.

The book can fairly claim to be a comprehensive handbook on the subject and has the further merit of being exceedingly well-produced.

G. PARR

MODERN PRACTICAL RADIO AND TELEVISION

This work covers every phase of Radio and Television Engineering from many viewpoints and meets a great demand. The author, C. A. Quarrington, A.M.Brit.I.R.E., with a long and wide experience of [Radio Engineering, has been responsible for training a large proportion of the Radio and Television Service Engineers in this country, and is also well known as a lecturer on Radio and Cathode-ray subjects to Universities, Radio Societies, Trade Associations and other interested bodies throughout the country.

SOME OF THE CONTENTS

Sound—Waves in Free Space—Electricity—Magnetism and Inductance—Capacity—Reactance and Impedance—Alternating Current—Tuned Circuit—Principles of the Thermionic Valve—The Signal Analysed—Detection—Reaction and Damping—H.F. Tetrode and Pentode—High-frequency Amplification—Principles of the Superheterodyne—Frequency-changing Valves—Design of the Superheterodyne—Practical Coil Design—Switches and Switching—Low-frequency Amplification—The Output Stage—Output Valves—Loudspeaker—Automatic Volume Control—Tuning Indicators—Interstation Noise Suppression—Automatic Tuning—Frequency Modulation—Power Pack—Decoupling—Gramophone Pick-up—General Mechanical and Electrical Considerations—Five Circuits Analysed—Aerials, Earths, and Noise Suppression—Car Radio—Principles of Low-power Transmission—High-Vacuum Cathode-ray Tube and its Application to Television—Time Base—Television Technique—Television-receiver Design—Adjustments and Faults of a Television Receiver—Measuring Instruments—Ganging Oscillator—Cathode-ray Oscillograph—Voltage and Current Testing—Instability and Motorboating—Tracing Distortion—Tracing Mains Hum—Tracing Background Noise—Valve Testing—Receiver Alignment (Ganging)—Whistles and Breakthrough — Loudspeaker Faults — Testing Components—Fault-finding Procedure (A Summary)—Local Interference—Workshop Hints—Accumulator Charging and Maintenance—Simple Mathematics, etc.—Abridged Technical Dictionary.

THE ILLUSTRATIONS

"Modern Practical Radio and Television" is profusely illustrated. It contains 16 full-page plates, over 400 diagrams in the text and 7 large folding insets. Each illustration has been specially selected for its practical utility.

A FREE PAMPHLET

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Please send me, free of charge, Pamphlet describing "Modern Practical Radio and Television."

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Send this form in unsealed envelope (1d. stamp)

Address .....

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MARCH MEETINGS

*NOTE.— In general, visitors are admitted to the meetings of scientific bodies on the invitation of a member, or on application in writing to the Organising Secretary at the address given. In certain cases (marked *) tickets may also be obtained on application to the Editorial offices of this Journal.*

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Radio Section

Date: March 19. Time: 5.30 p.m.
Lecture: "Velocity Modulation Valves."
By: L. F. Broadway, B.Sc., Ph.D., C. J. Milner, M.A., Ph.D., D. R. Petrie, W. J. Scott, and G. P. Wright.

Radio Communication Convention

Date: March 25. Time: 5.30 p.m.
Opening ceremony by Sir Stafford Cripps, P.C., K.C., M.P., introducing
Address: "Telecommunications in War."
By: Colonel Sir Stanley Angwin, K.B.E., D.S.O., M.C., T.D.

Date: March 26. Time: 9.45 a.m.
Lecture: "Long Distance Point-to-Point Communication."

Date: March 26. Time: 11.30 a.m.
Lecture: "Naval Communication."

Date: March 26. Time: 2.30 p.m.
Lecture: "Military and Aeronautical Communication."

Date: March 26. Time: 6 p.m.
Lecture: "Pulse Communication."

Date: March 27. Time: 9.45 a.m.
Lecture: "Short-Distance Communication—1."

Date: March 27. Time: 11.30 a.m.
Lecture: "Short-Distance Communication—2."

Date: March 27. Time: 2.30 p.m.
Lecture: "Direction-Finding."

Date: March 27. Time: 6 p.m.
Lecture: "War-Time Broadcasting."

Date: March 28. Time: 9.45 a.m.
Lecture: "Propagation."

Date: March 28. Time: 2.30 p.m.
Lecture: "Radio Components."

Date: March 28. Time: 6 p.m.
Lecture: "Review of the Convention and Future Trends."
By: Sir Clifford Paterson, C.B.E., D.Sc., F.R.S.

Date: April 2. Time: 5.30 p.m.
Lecture: "C.W. Navigational Aids."

Measurements Section

Date: March 7. Time: 5.30 p.m.
Discussion on—"Recent Developments in Calculating Machines."
Opened by: Professor D. R. Hartree, M.A., Ph.D., M.Sc., F.R.S.
Date: March 21. Time: 5.30 p.m.
Lecture: "The Design and Construction of a new Electron Microscope."
By: M. E. Haine, B.Sc.

Cambridge Radio Group

Date: March 11. Time: 6 p.m.
Held at: The Cambridge Technical College.
Lecture: "U.H.F. Triodes on Velocity-Modulation Tubes."
By: G. W. Warren, B.Sc.

North-Eastern Centre

Date: March 24. Time: 6.15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-on-Tyne.
Lecture: "Industrial Applications of Electronic Techniques."
By: H. A. Thomas, D.Sc.
Hon. Secretary: L. Mellor, "Burn Brae," Heworth, Gateshead, 10.

North-Eastern Radio and Measurements Group

Date: March 3. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: "The Design of High-Fidelity Disc-Recording Equipment."
By: H. Davies, M.Eng.

South-Midland Radio Group

Date: March 24. Time: 4 p.m.
Held at: James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: "The Elements of Wave Propagation using the Impedance Concept."
By: H. G. Booker, M.A., Ph.D.
Hon. Secretary: E. May, Birlec Ltd., Tyburn Road, Birmingham, 24.

The Television Society

Date: April 1. Time: 6 p.m.
Annual General Meeting (members only).

Constructors' Group

Date: March 14. Time: 7 p.m.
Held at: E.L.M.A. Bureau, Savoy Hill, W.C.2.
Lecture: "A Television Receiver for Home Constructors—Part 2.
By: W. I. Flach.
It is hoped to follow the meeting with a demonstration of the receiver.
Lecture Secretary: G. Parr, 68, Compton Road, London, N.21.

The Institute of Physics

Midland Branch

Date: March 15.
Held at: The University, Edmund Street, Birmingham.
Lecture: "The Acceleration of Electrons and Ions to Energies of the order of 10^8 Electron-volts."
By: Prof. P. B. Moon, F.Inst.P.
Note: This is a joint meeting of the London Section, Electronics Group.
Hon. Secretary: Dr. J. H. Nelson, Messrs. Joseph Lucas Ltd., Birmingham.

Brit. I.R.E.

Edinburgh Section

Date: March 19. Time: 6.30 p.m.
Held at: The Heriot-Watt College, Edinburgh, 1.
Lecture: "The Boundary between Sinusoidal and Relaxation Oscillation."
By: E. Williams, Ph.D., B.Eng.
Hon. Secretary: H. G. Henderson, 5, Muirburn Avenue, Muirend, Glasgow, S.4.

The British Sound Recording Association

Date: March 27. Time: 7 p.m.
Held at: The Royal Society of Arts, John Adam Street, London, W.C.2.
Lecture: "Developments in Magnetic Wire Recording."
By: P. T. Hobson.

The British Kinematograph Society

Sub-standard Film Division Meeting

Date: March 26. Time 7.15 p.m.
Held at: The Wellcome Foundation, 183, Euston Road, London, N.W.1.
Lecture: "Problems of 16 mm. Projection."
By: G. H. Sewell, A.R.P.S., and H. S. Hind, A.M.I.E.E., A.R.P.S.

Society of Instrument Technology

Date: March 25. Time: 7 p.m.
Held at: Royal Society of Tropical Medicine and Hygiene, London, W.1.
Lecture: "Electronics in Non-destructive Testing."
By: R. Meakin, B.Sc., A.Inst.P.

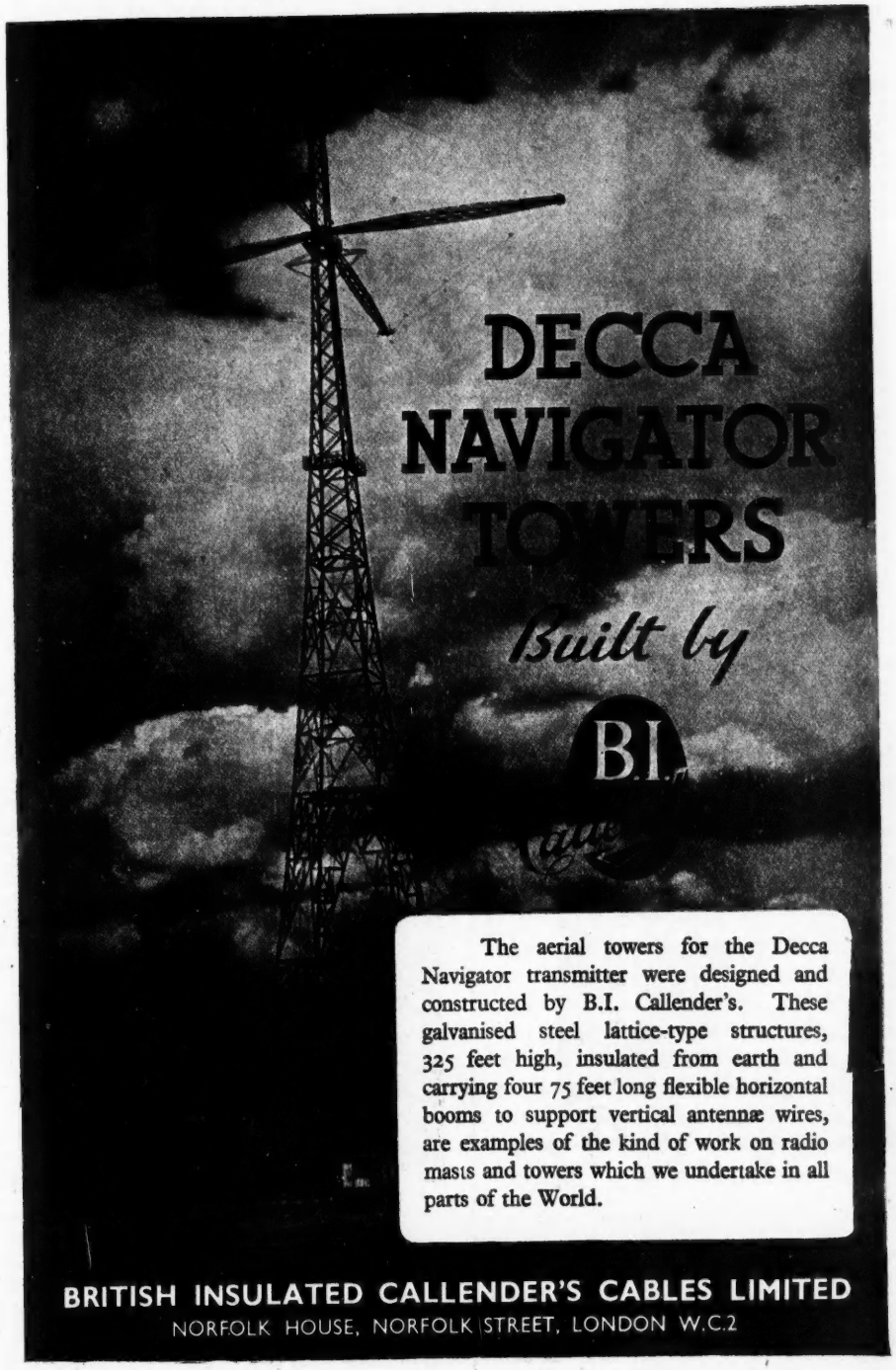
Thames Valley Amateur Radio Transmitters' Society

This Society, which is affiliated to the R.S.G.B. is open for membership to all keen amateur radio enthusiasts, and those interested are asked to contact the Hon. Secretary, G3JG, "Thurston," Orchard Way, Esher, Surrey, telephone number: Esher 3369.

Meetings are held on the first Wednesday in each month at the Carnarvon Castle Hotel, Hampton Court.

Exeter and District Amateur Short-Wave Radio Society

Meetings of the above Society are now being held regularly and those interested should apply to the Hon. Secretary, E. G. Wheatcroft, 7 Mount Pleasant Road, Exeter, Devon.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ABSTRACTS OF ELECTRONIC LITERATURE

MEASUREMENT

A Millisecond Chronoscope
(R. S. J. Spilsbury and A. Felton)

This paper opens with a discussion of various methods of measuring short time intervals and then proceeds to describe a condenser chronoscope suitable for the measurement of intervals initiated and terminated by momentary or sustained makes or breaks in electrical circuits. The range is from 2 millisec to 1,000 millisec. The voltage on the condenser is measured by a simple valve voltmeter which is used only as a transfer instrument, the final reading being given on three decade dials of a potentiometer. This reading is converted into milliseconds by the use of specially prepared tables.

The instrument is self-contained and transportable, power being obtained from dry batteries. The accuracy, which is limited chiefly by dielectric absorption in the condenser and by leakage in the components, is of the order of 0.5 millisec on short intervals or 0.5 per cent. on long intervals.

—*Jour. I.E.E.*, to be published.

The Electrical Measurement of Pressures and Indicator Diagrams
(E. J. B. Willey)

A brief discussion is given of the various methods for electrical measurement of pressure. Apparatus of a simple kind is then described, with working details, (a) for two pressure condensers, (b) for a capacity-coupled amplifier usable down to 5 c/s, (c) for a direct-coupled cathode-follower circuit and (d) for special non-linear time bases to convert pressure-time curves into indicator diagrams.

—*Jour. Sci. Inst.*, Nov. 1946, p. 264.

Application of the Ion Gauge in High Vacuum Measurement
(H. E. van Valkenburg)

The ionisation-type vacuum gauge can be used in applications where pressures less than 10^{-7} atmospheres are to be measured. Pressure indications may be obtained for the highest vacuums used in ordinary processes. The useful features, circuit requirements and inherent limitations of such a gauge are presented with relation to its effective application. In particular, the design of an electronic control unit and the use of standardised gauge valves are described.

—*Gen. Elec. Rev.*, June, 1946, p. 38.

TELEVISION

Television Equipment for Guided Missiles
(C. J. Marshall and L. Katz)

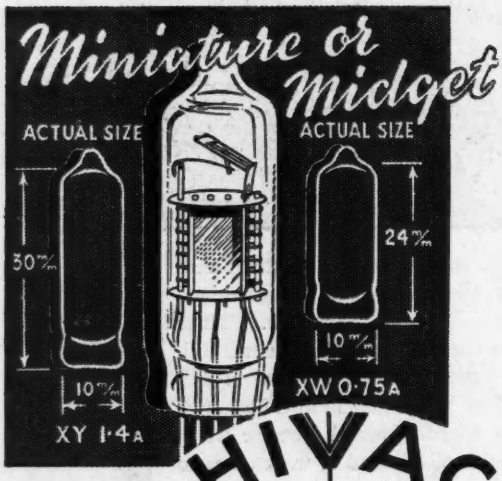
A brief history of the technical problems associated with the development of compact airborne television equipment is outlined. The system provides resolution, linearity and stability which approaches that obtained from broadcast equipment. Technical difficulties which arose after the completion of the equipment design are described. The final solution of these and other problems resulting from its installation in guided missiles are discussed. Photographs taken from the receiver screen during experimental flights are shown.

—*Proc. I.R.E.*, June, 1946, p. 375.

Development of an ultra low loss Transmission line for Television
(E. O. Johnson)

The development of a low loss 300 ohm parallel wire polyethylene dialectric transmission line is described. Loss curves, as well as a photograph of a production run sample of the line are included.

—*R.C.A. Review*, June, 1946, p. 272.



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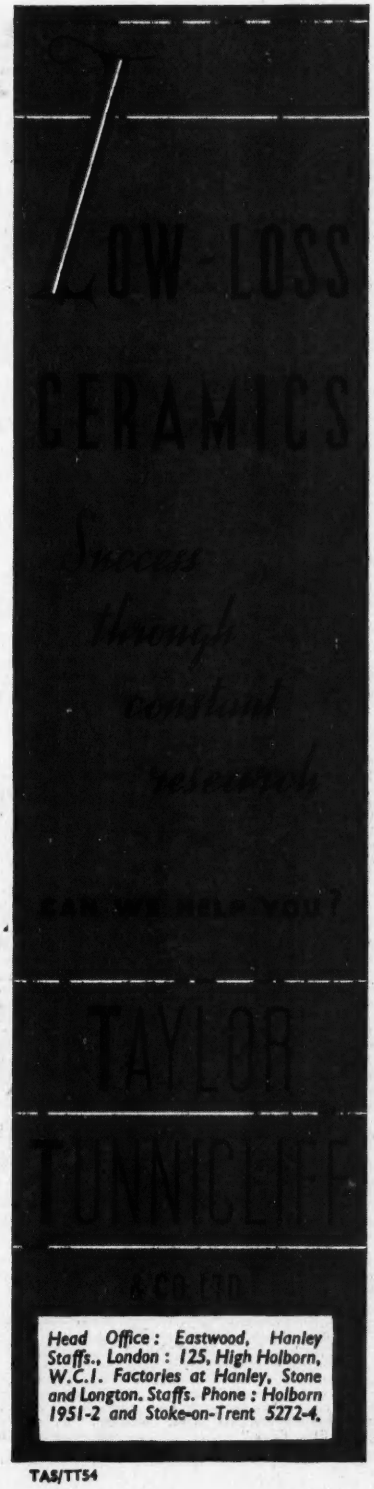
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CLASSIFIED ANNOUNCEMENTS

The charge for miscellaneous advertisements on this page is 12 words or less, 5/- and 4d. for every additional word. Box numbers count as four words, plus 1/- extra for replies. Remittance should accompany advertisement. Cheques and P.O.'s payable to Hulton Press, Ltd., 43 Shoe Lane, E.C.4. Replies to box numbers should be addressed as above, marked "Elec. Engg." Press date: 15th of month for following issue.

FOR SALE

AMATEUR RADIO GEAR. We have a large range of new Radio and Sound Equipment, including valves and tuning packs. 3 Waveband Coil Packs with dial drive, completely wired in with all instructions, 65/-. 3-Waveband Tuning Heart with I.F. stage wired in and complete with 6K8 mixer and 6SG7, latest high-gain I.F. pentode, ready aligned, £5. The complete radio wired into two separate chassis with all valves, etc., and ready to work, 175/-. Miniature A.C./D.C. Amplifiers for use with microphone and gram. input or for use with Radio Tuners and Super Regenerative Receivers. 12 watts, 12 gns.; compact 6 watt, 10 gns. Both in self-contained metal cabinets with multi-match speaker output. 5-watt A.C./D.C. Amplifier on chassis, complete with valves, 85/-. American metal and GT type valves, 6SN7, 12SK7, 6SJ7, 6SG7, EF50, EA50, 807, 832, DET20, 7A7, 7S7, 7H7, IN5, 9003, IT4. IT5, etc. Bendix super quality 6-waveband Communication Receiver, with 12-in. speaker, 75 gns. complete. Marconi 5-waveband Receiver as 6-valve tuner, 25 gns.; complete with 15 watts output, 42 gns. Electronics 7-valve model, complete in metal cabinet, 1 microvolt sensitivity, single-ended valves used throughout, BFO, RF gain control. 16-500 metres. For use on A.C. mains or special model for 6 v. or 12 v. operation. 12 months' guarantee. 32 gns Send for our 12-page catalogue of components, valves, high-frequency receivers, communication equipment and high quality amplifiers. United Electronics, Ltd., Electron House, 655, Fulham Road, London, S.W.6. (RENown 4178)

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A SET OF BOUND VOLUMES, "Electronics and Television," 1935 to 1940 complete. Also copies of "Electronic Engineering, January, 1941, to November, 1946 (less July and August, 1941). Offers?—G. Short, Lynch House, Fowlmere, Royston, Herts.

CAMBRIDGE INSTRUMENTS Unipivot Micro-ammeter, 6-in. scale, 3-0-3; 870 ohms. New, £10. Box 979, "Elec. Engg."

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MISCELLANEOUS

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A WELL KNOWN technical publishing house will be pleased to consider manuscripts for publication, dealing with all aspects of radio and television. Treatment of subject should be moulded on practical lines with emphasis laid on data for the actual construction of apparatus. Manuscripts should be of 10,000 words and upwards, and should be submitted complete with finished or rough drawings. Box AC 16559, Samson Clarks, 57/61, Mortimer Street, W.1.

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A FIRM IN LONDON requires communication engineer with considerable experience of radio circuit design especially on aircraft equipment and miniaturisation. Good basic training and subsequent industrial experience essential. Post will be responsible one with very interesting prospects for right man. Initial salary up to £850 per annum. Write full details of education, qualifications and experience to Box 922, "Elec. Engg."

ENGINEERS required for research and development department of a firm in the London area. Previous experience on the development of electronic components necessary. Applicants should write stating age and experience to Box 943, "Elec. Engg."

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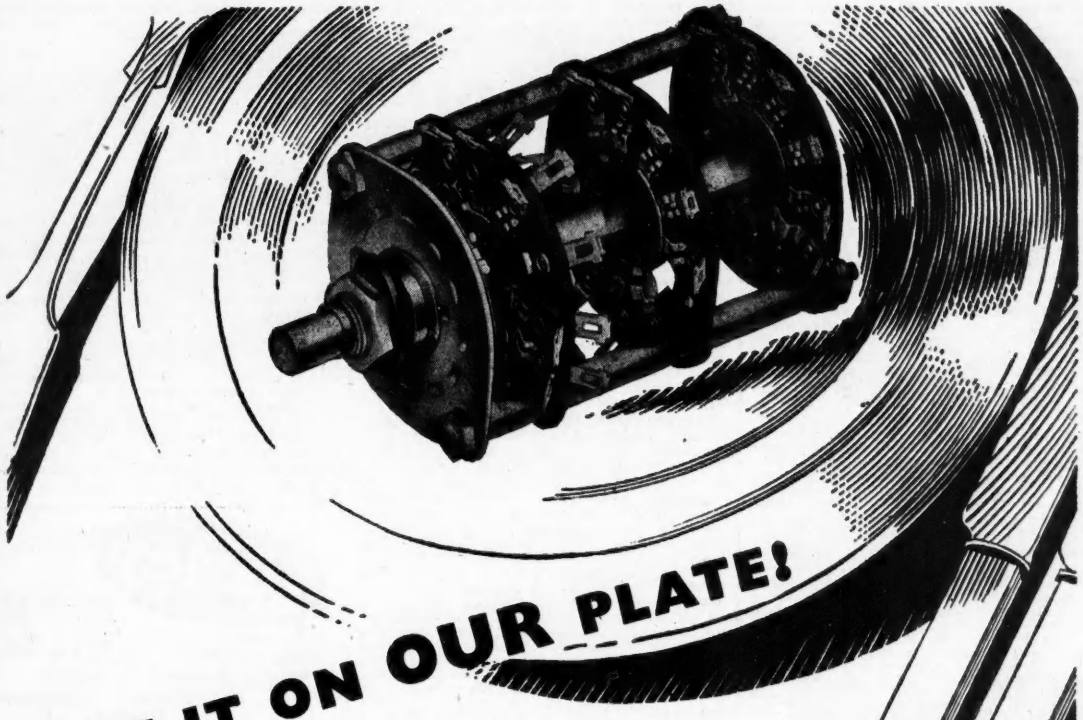
PRODUCTION DEVELOPMENT Engineer required by a large firm in Essex engaged in the light engineering industry. Applicants must have sound technical experience of jig and tool design and experience of layout of mass production assembly lines. Applications should state technical qualifications, age, experience, and salary required to Box 976, "Elec. Engg."

continued on p. xx.



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SENIOR DRAUGHTSMEN required with experience in design of radio equipment and components, A.E.S.D. rates and over, according to ability. Apply Personnel Manager, E. K. Cole, Ltd., Malmesbury, Wilts.

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A DEVELOPMENT ENGINEER is required for radio frequency heating in a laboratory at High Wycombe. Applicants should have an honours degree or equivalent, and should have a sound knowledge of mechanical engineering, together with previous development or research experience. Experience to have covered several of the following subjects: mechanical or production engineering, power switchgear, transformers and rectifiers, high-power radio transmitting equipment and particularly R.F. dielectric heating. Applications in writing to the Personnel Manager, P.R.T. Laboratories, Ltd., Cressex, High Wycombe, Bucks, quoting reference VLH/PHW.

JUNIOR ENGINEER required for development work at a London firm of radio components manufacturers. Degree and practical experience on component development important. Salary, £400 upwards. Apply Box 981, "Elec. Engg."

SENIOR DRAUGHTSMAN required, with experience in light electrical engineering, for work on prototype equipment in connection with television transmitters. Detail draughtsman also required for similar work. Apply by letter to the Research Laboratories of the General Electric Co., Ltd., N. Wembley, Mddx.

LABORATORY ASSISTANT required for acoustics laboratory dealing mainly with hearing aid investigations. Applicants should be between 20 and 30 years of age, should hold a National or Higher National Certificate in engineering or electrical engineering, or have had equivalent experience. Initiative and adaptability are more essential qualifications than previous experience of audio-frequency work. Salary according to qualifications, with superannuation. Apply Secretary, National Institute for the Deaf, 105, Gower Street, London, W.C.1.

LABORATORY ENGINEERS are required for development work on broadcast receivers. The laboratory is south-west of London, 30 minutes from Waterloo. Please write, stating age, salary expected, experience and qualifications. Box 984, "Elec. Engg."

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(B) One Mechanical Designer. Radio experience and degree or equivalent essential. Salary, £430/590 p.a.

(C) One Technical Assistant. Radio experience essential. Salary £6 per week upwards, according to experience. Box 990, "Elec. Engg."

ASSISTANT, age 17/20 required to assist in test gear section of London plant manufacturing radio components. National or City and Guilds certificate student essential. Apply Box 974, "Elec. Engg."

RADIO MECHANICS and electricians required for company operating York and Lancaster aircraft. Write, giving full particulars of past experience and present employment to Box 983, "Elec. Engg."

RADIO AND ELECTRONICS Research and Development Engineer required with wide experience on V.H.F., miniaturisation and electro-mechanics. West London district. In applying give full details of experience, qualifications, age and salary required, to Box 989, "Elec. Engg."

TRANSMITTER DESIGN Engineer required by E.M.I. Factories, Ltd. Substantial salary and good prospects for suitably qualified man. Write, giving full particulars, experience, etc., to E.M.I. Factories, Ltd. (T.D.E.), Hayes, Middlesex.

ELECTRONIC ENGINEER, Inter. B.Sc. standard, with production experience, required to take charge of quantity production and testing of amplifiers in Glasgow. Experience of sound film equipment an advantage. Write, giving particulars of qualifications, experience, and salary required, to Box 991, "Elec. Engg."

PHYSICIST required by research department in West London area for work upon cable dielectrics. Candidates must have a degree and preferably have good experience of electrical measurements. Write, giving details of age, qualifications, experience, and salary required to Box No. 323, c/o Whites, Ltd., 72, Fleet Street, E.C.4.

DRAUGHTSMAN, Junior, required, with experience of radio circuits and assemblies. Some technical knowledge desirable. Excellent opportunity for young improver to better position. Box 986, "Elec. Engg."

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(A) Radio Engineers for station in south of England. Various grades open for transmitter engineers at salaries £250 to £600 p.a., according to experience and ability. Basic engineering training up to B.Sc. standard preferred in higher grades, but there are vacancies for men with sound knowledge of radio communications and workshop practice.

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ENGINEER required for vibration and mechanical test work on high-speed diesel engines. Knowledge of electronic equipment and its maintenance essential. Write, stating details of experience, age and salary required to Box 975, "Elec. Engg."

APPLICATIONS are invited for the position of physicist in a television laboratory. Qualifications of applicant must include experience of radio or electronic engineering, a B.Sc., or equivalent, and at least 4 years' industrial experience, preferably in television. Knowledge of optics desirable. Salary, £450/700, according to age and qualifications. Age 25/35. Apply to: Ref.: TEL/VLH, Personnel Manager, P.R.T. Laboratories, Ltd., Commonwood House, Nr. Chipperfield, Herts.

ELECTRICAL ENGINEERING MANUFACTURERS in the Midlands require Engineers with specialist knowledge of electronic control circuits and equipment. Must have studied communication engineering to Degree standard or equivalent. Also have sound general experience in electrical and mechanical engineering and ample practical experience in industrial electronic engineering. Age 28 to 35 preferred. Reply Box No. 993, "Elec. Engg."

JUNIOR ENGINEER required for development of processes on radio components, in London area. Higher National Certificate in Electrical Engineering or equivalent essential. Box No. 994, "Elec. Engg."

DEVELOPMENT ENGINEERS required by firm in the Manchester area. Applications must have had experience in development of radar equipment and preferably some knowledge of Gee. Please reply giving full particulars of age, qualifications and experience. Box No. 995, "Elec. Engg."

REQUIRED BY FACTORY IN LONDON a Senior Radio Engineer with sound technical training and experience of high power high frequency engineering, for development of industrial electronic equipment. State qualifications, experience, age and salary required to Box No. 996, "Elec. Engg."

SITUATIONS WANTED

ELECTRONIC ENGINEER, 31, 14 years' experience, ex-A.I.D. (radar), C. and G. etc., seeks post, lab. or test department. Keen, accurate worker. Box 977, "Elec. Engg."

ELECTRICAL ENGINEER, 26, honours degree, works apprenticeship, experience research on arc rectifiers and small vacuum devices, glass-metal seals, etc., requires post with prospects of advancements. Box 987, "Elec. Engg."

ELECTRONIC ENGINEER, 20 years' experience, ex-Naval Radar Lieut. Excellent connection Scottish shipyards and Scottish electrical firms. Seeks responsible position. Car available. Box 982, "Elec. Engg."

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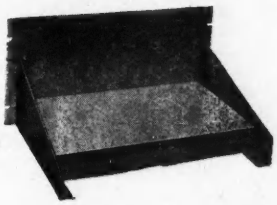
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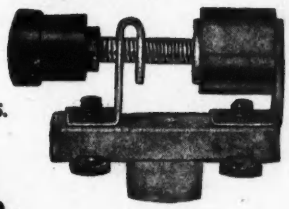
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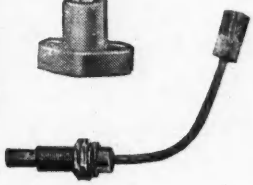
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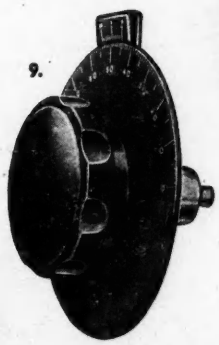
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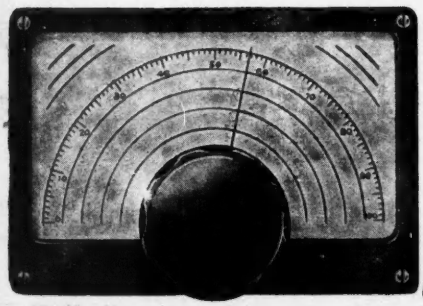

A WORD OF WARNING. All "Eddystone" components are *usually* available from stock at Webb's, but post customers are advised to enquire before ordering.

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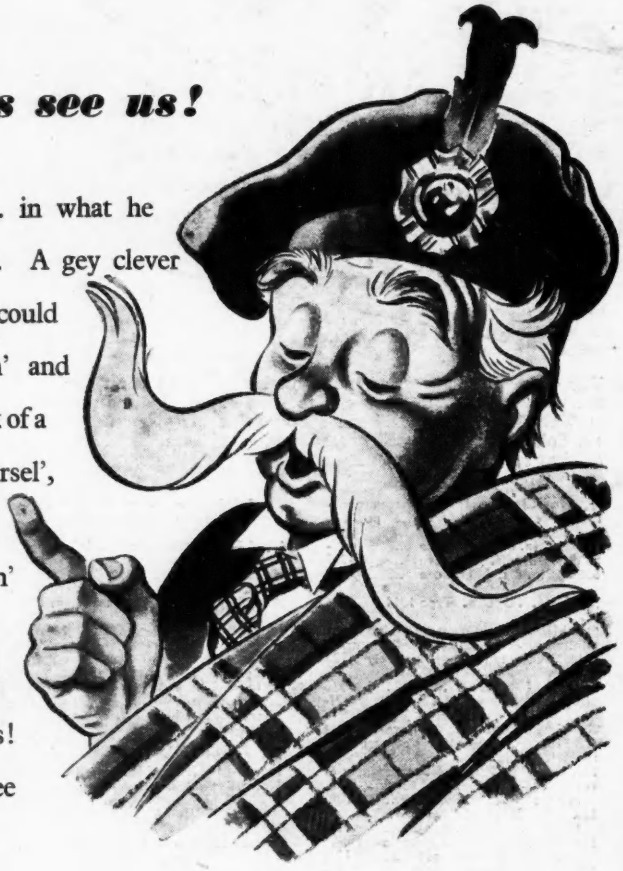

Hoots Toots! (says the M.D. in what he imagines to be a Scots accent). A gey clever laddie was oor Rabbie. If ye could see yoursel' the noo, ditherin' and a mitherin' wi' that auld puddock of a tool and michty pleased wi' yoursel', nae doot! D'ye no ken that therre are fine wee toolies worrkin' wi' electrricity and such that wad dae your worrk in hauf the time at a huge savin' o' bawbees! Losh, mon, if ye could juist see yoursel . . . . !

Cor, stone the crows mate! If you could take a gander at yerself you'd take a runnin' jump into the Frith of Froth!

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